Exploring the relative effectiveness of functionally embodied and non-functionally embodied early literacy interventions

by

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Abstract

The theory of embodied cognition provides a precise explanation for the positive effects of multisensory instruction methods, which are widely implemented for early literacy acquisition. Embodied instruction methods show great promise in learning across academic areas but have yet to be directly applied to the field of early literacy skills. The purpose of the current study is to examine the relative effectiveness of functionally embodied and non-functionally embodied early literacy interventions. An adapted alternating treatment design comparing a functionally embodied and a non-functionally embodied early literacy intervention was conducted with three elementary aged students demonstrating difficulty with early literacy. Accuracy of pseudoword CVC wordlist decoding increased at a higher rate and the number of trials to mastery was smaller for the functionally embodied condition compared to the non-functionally embodied condition with three demonstrations of the effect by two participants and one demonstration by the third participant. Additionally, all three participants showed improvements in phonics knowledge and broad reading skill from pre to post intervention. These findings have important implications for the use of embodied instructional techniques in education and for the use of theory to derive intervention practices.

Lay Summary

Some students struggle to learn letter sounds. Many educators try to include movement and multiple senses to help teach students to read. This study provided a theory for why this may be a good idea and compared two ways to do this. This study combined proven strategies for teaching letter sounds with a movement that was either related to the shape of the letter or a movement that was unrelated to the letter shape. We found that students' were faster to learn letter sounds when they learned with a movement related to the letter shape then when the movement was not related to the letter shape.

Preface

The present study was conducted by Rachel King (primary research graduate) under the supervision of her supervisor, Dr. Sterett Mercer. The primary research graduate collected, and analyzed the data. A secondary research graduate conducted inter-observer agreement. The research conducted was approved by the University of British Columbia Behavioral Research Ethics Board (BREB) under certificate H17-03514.

Table of Contents

List of Tables

List of Figures

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I. Introduction

Literacy remains a significant issue in Canada with only 62% of adults reading at a level considered to not interfere with living (Statistics Canada, 2013). At least a quarter of youth in Canada do not graduate high school and reading is the greatest predictor of graduation (Statistics Canada, 2008). However, a lack of evidence-based interventions has been implicated in failures to support development of literacy skills (Canadian Education Statistics Council, 2009). Therefore, to assist development of literacy skills in school-aged children research must focus on the development of empirically supported interventions.

Similarly across North America, only 38% of grade twelve students in the US perform at or above the "proficient" level in reading (National Center for Educational Statistics, 2009). Struggles with learning to read are also evident at younger ages. More than a third of grade four students, and over half of minority group students, in the US are performing below the "basic" level of skill in reading comprehension on the National Assessment of Educational Progress (Al Otaiba et al., 2011a). As early as Kindergarten, literacy difficulties are evident in students' lack of pre-reading skills; for example, only half of students this age have developed proficiency in letter-sound relationships (Simmons et al., 2007). Additionally, struggling readers have been shown to encounter the Matthew Effect, where "the rich get richer and the poor get poorer", and continue to fall behind their peers in reading skill (Juel, 1988; Stanovich, 1986). Growing evidence that it is challenging to remediate reading skill in older students points to a need to focus on early reading intervention (Al Otaiba, et al., 2011a).

Evidence supports implementing early, systematic, and directed evidence-based interventions to assist students at-risk for reading difficulty in catching up to their peers (Al Otaiba et al., 2011a; Al Otaiba et al., 2011b; National Reading Panel, 2000; Schatschneider, Fletcher, Francis, Carlson & Foorman 2004; Shanahan & Lonigan, 2010; Torgesen, 2000). Further, Coyne, Kame'enui, Simmons, and Harn (2004) demonstrated that intervention in Kindergarten could produce an inoculation effect, such that early intervention produces a lasting effect in preventing reading difficulties, supporting early intervention for prevention of reading difficulty in students.

Many studies highlight the importance of explicit instruction of the alphabetic principle in early grades (Campbell & Cooke 2008; NRP, 2000; Snow, Burns, & Griffin, 1998; Stage, Sheppard, Davidson, & Browning, 2001). The alphabetic principle is defined as knowledge of how phonemes (units of sound in language) map onto graphemes (letters; Beck & Beck, 2013). Ehri (1998) provided a review of the many studies that indicate phoneme-grapheme knowledge is a necessary skill for word reading. Additionally, in a meta-analysis of phonological awareness interventions, those that used graphemes to represent the sounds were most successful (Ehri et al., 2001) supporting the alphabetic principle as the most appropriate target for early intervention.

Multisensory Approaches

Multisensory approaches to learning were first proposed by Montessori (1915), were built upon by Dr. Samuel Orton throughout the 1920s and are still widely used in schools today (Bara, Gentaz, Cole, & Sprenger-Charolles, 2004). Orton believed that reading problems were, in part, caused by a lack of hemisphere dominance resulting in the processing of reading information in both occipital poles, and therefore the

production of mirror images (Eden & Moats, 2002; Ritchey & Gooke, 2006). When building a curriculum with his colleagues, Gillingham and Stillman (The Orton-Gillingham or OG curriculum), Orton supported multisensory instruction methods as a means to simultaneously recruit both left and right brain hemispheres (Gillingham & Stillman, 1997). Multisensory instruction methods refer to the inclusion of visual, auditory and tactile-kinesthetic strategies to improve learning (Campbell & Cooke, 2008; Moustafa, 1999).

While thoughts from this time period about the causes of reading disabilities have not stood up to the scrutiny of recent research, the interventions based on them, including the OG and multisensory approach, are still frequently delivered and are widely accepted (Ritchey & Gooke, 2006). Despite their wide implementation, current evidence suggests that the original basis for implementing multisensory interventions for reading problems is no longer valid. It has been shown that reading, especially of elementary linguistic stimuli, already involves bilateral activation (Levy et al., 2008) indicating multisensory methods are unnecessary to achieve the original goal. Additionally, no effect on a neurobiological substrate for reading has been demonstrated through the use of multisensory methods (Eden & Moats, 2002).

Theoretical explanations of multisensory instruction. Despite limited support for the original bilateral activation hypothesis, a number of other, more recent, theories have been put forward to support the continued use of multisensory methods. The primary theory among these is those students who learn to read through multisensory techniques benefit from the phenomenon of multisensory integration (Carreiras, Quinones, Hernandez-Cabrera, & Dunabeitia, 2014; Moustafa, 1999; Murphy, 1997).

Multisensory integration is the creation of a unitary cognitive representation through the combination of information from multiple sensory modalities (Stevenson et al., 2014). When multisensory integration occurs, both speed and accuracy of perceptual decision-making are improved (Naue et al., 2011). This theory suggests that while initially the child labors to remember letter-sound correspondences, when correspondences become automated, just the sight of a given grapheme activates the phonological representation (Hahn, Foxe, & Molholm, 2014). On the surface, this theory provides a potential explanation for a benefit to be conveyed by multisensory techniques. However, there are some critical flaws to this theory.

One such flaw with this theory is that research has indicated that for multisensory integration to occur, the presented stimuli must be both semantically and temporally congruent (Kim, Seitz & Shams, 2008). Since letters and speech sounds are, essentially, arbitrary associations, they lack the semantic conectedness of natural audiovisual integration, making letter-sound integration both more vulnerable and more effortful, and highly unlikely to be integrated to form a unitary percept. Additionally, the lack of semantic congruency serves to further shorten the already narrow time window for the integration of letters and speech sounds. Further, Blomert (2011) identified a specific cross-modal binding deficit of letters and speech sounds which can interfere with, or slow down, any integration. Together this evidence demonstrates that while multisensory integration has the pontential to facilitate learning, it is highly unlikely that it actually occurs, particularly in the context of the acquisition of early reading skills.

A second challenge to the multisensory integration theory as support for the use of multisensory techniques, is its applicability to students with reading challenges,

specifically reading based learning disabilities. In a study looking at the role of multisensory integration in learning phonological associations both in typically developing students and students with reading learning disabilities, it was demonstrated that students with reading learning disabilities have greater difficulty integrating letters and speech sounds; their integration is described as “sluggish”, and therefore, they benefit less from integrating auditory and visual information in this context (Harrar et al., 2014). This further undermines the theory that multisensory methods in reading interventions facilitate learning through multisensory integration since these interventions are designed for struggling readers, a significant portion of whom have reading learning disabilities and are therefore unlikely to benefit from integration.

Another theory put forward to support the use of multisensory methods is that of sequential processing (Gentaz & Rossetti, 1999; Hatwell, Streri & Gentaz, 2000). This theory postulates that there are positive effects of multisensory methods because of the functional specificities of the different sensory modalities involved. Vision is characterized by simultaneous processing, appropriate for the representation of spatial information, such as that in letters. In contrast, audition involves sequential processing, suitable for the temporal stimuli of speech sounds. Sequential processing is thought to facilitate a more analytical level of information processing and this theory suggests that the introduction of haptic exploration of letter stimuli results in sequential processing of spatial information, bridging the gap between the auditory and visual information, to assist the learning process. However, Bara, Gentaz, Cole and Sprenger-Charolles (2004) evaluated this theory by comparing learning in an audio-visual and haptic exploration condition and an audio-visual condition where the visual information is presented

sequentially. The haptic condition was significantly more successful than the sequential processing, indicating that sequential processing alone is not sufficient to produce a positive effect and support the use of multisensory methods.

Beyond the theories of multisensory integration and sequential processing, other less developed theories have been put forward to support the use of multisensory techniques. One suggestion is that presenting information in auditory, visual, tactile and kinesthetic modalities helps to anchor the verbal information by creating nonverbal mental representations (Oakland, Black, Stanford, Nussbaum and Balise, 1998). Another suggestion comes from observations of the strong interactive influences between the development of spoken language and learning to read (Perfetti et al., 1987), which indicates that cross-modal processing phonemes and graphemes might be influential in the successful learning process (Blomert, 2011). While both of these theories show promise they are still vague suggestions, lacking support.

A variety of theories to support the use of multisensory techniques have been presented over the years. What is evident from a review of the literature is that few of these theories are well developed, and those that are do not stand up to scrutiny. As yet there is no strong theory to support the use of multisensory techniques in interventions. Therefore, it is important to consider what evidence exists for the success of these techniques.

Evidence for multisensory instruction. There is not a strong body of research evaluating multisensory teaching methods. Likely due to its wide-spread implementation, a significant proportion of of this research is centered on OG or OG based methods. Even so, OG has limited research on its efficacy (Campbell & Cooke, 2008). A What Works

Clearinghouse report (Institute of Education Sciences, 2010) indicated that no OG studies met their design standards. Other reviews, with less stringent inclusion criteria found mixed evidence for efficacy and reported that OG is no more effective than other systematic reading interventions (Alexander & Slinger-Constant, 2004; Ritchey & Goeke, 2006; Turner & Herbert, 2008). For example, both Hook (2001) and Eden and Moats (2002) demonstrated that OG and FastForWord, with structured language teaching, showed equal outcomes. Ritchey and Goeke (2006) suggest that when the small number of studies that evaluate OG are considered alongside the lack of methodological rigor in these studies and their inconclusive findings regarding efficacy, it indicates that OG and OG based instruction should not be considered an evidence-based reading intervention. Therefore, it appears that the continued use of OG methods is based mostly on clinical experience and anecdotal evidence (Henry, 1998; Ritchey & Goeke, 2006).

There is a paucity of research that evaluates the multisensory methods that are included in reading interventions, outside of OG, but those that do appear to show initial promise for their efficacy. Historically, Fernald (1943) developed a technique, called the "multisensory trace" based on Montessori's principles. This technique involves struggling readers tracing a written word with their index finger while looking at it and pronouncing the word. His results indicate this to be a successful technique and the findings have been replicated, although, at over thirty years old they would benefit from further evaluation (Hulme, 1981; 1979). A recent study by Labatt and colleagues (2015) concludes that multisensory kinesthetic methods are more effective than unisensory methods in the acquisition of the alphabetic principle by employing the use of blindfolding to isolate the senses. Specifically, they found that conditions that included

either a graphomotor or letter tracing condition when not blindfolded were most successful, interpreted to support the use of multisensory methods. It appears that beyond these studies, the majority of other research in this area has been published by The International Dyslexia Foundation, a foundation dedicated to the memory of Orton, and is therefore likely to have been conducted with a bias toward the efficacy and use of multisensory methods (Campbell & Cooke, 2008; Cox, 1985; Joshi, Dahlgren, & Boulware-Gooden, 2002). Any other research is heavily criticized for poor research designs, employing a non-parallel control intervention, poor operationalization of the multisensory methodology, or evaluating the multisensory method as part of a whole intervention package (Campbell & Cooke, 2008). Therefore, based on the age, potential bias, and poor construction of the majority of the research evaluating multisensory methods, there is little reliable evidence that remediating the sensory systems translates into improvement in reading skill.

Embodied Cognition Approaches

Embodiment theories, which have been receiving increased support from behavioural and neuroscientific studies, suggest there are close links between the sensorimotor brain system and cognition (Barsalou, Simmons, Barbey, & Wilson, 2003; Crollen, Dormal, Seron, Lepore, & Collignon, 2013; Kiefer and Trumpp, 2012). The theory of embodied cognition emphasizes the role of sensorimotor experiences, active exploration and manipulation of objects in learning (Borghi and Cimatti, 2010; Puow, van Gog & Paas 2014). Those involved in the field of embodied cognition are generally in agreement that cognition is mediated by body shape, movement and scale; the motor and action planning systems; and the systems involved in sensation and perception

(Alibali & Nathan, 2012; Glenberg, 2010). This post-cognitivist approach proposes that cognition no longer be thought of as amodal and fundamentally separate from action and perception; instead, it is viewed as being dependant on the body and the context (Ionescu & Vasc, 2014). It goes as far as to suggest that the body shapes cognition and that our cognitive representations are not separate from the sensorimotor systems through which they are experienced (Kiefer & Trumpp, 2012).

Within the embodied cognition literature, Barsalou's (2008; 1999) perspective, the Perceptual Symbols Systems Account, provides a clear description of how information is embodied. In his account, a concept is considered to be based on the re-activation of the specific neural patterns, in various modalities, that were activated during previous interactions with the concept. Barsalou also suggested that the activation patterns are interlinked, such that a single multimodal representation of the concept exists, and this is called a Perceptual Symbol. This account is endorsed across the literature and more simply put suggests that through reinstatement of external and internal states and actions, cognition is a mental simulation of the sensorimotor experience of the object, situation or concept (Ionescu & Vasc, 2014; Keifer & Trumpp, 2012; Puow, van Gog & Paas, 2014).

To date, there is no unified theory of embodied cognition and the term embodiment is used in many ways across domains of cognitive science (Nunez, Edwards & Matos, 1999). For example, it is used to refer to unconscious aspects of motor activity that underlie linguistic expression (Johnson, 1987; Lakoff, 1987), the psychological manifestations of bodily experiences (Rosch, 1994), and the phenomenological aspects of bodily experiences (DiSessa, 1983). This wide variation in application and lack of

unified theory creates challenges to conducting research in this area. However initial findings provide support for the approach of embodiment.

The growing body of research providing support for the embodied cognition approach has demonstrated a role of the sensorimotor system in in a variety of cognitive processes. Some of these include reading, problem solving, and mental computation (Puow, van Gog & Paas, 2014). A learning related example comes from Chao, Huang, Fang and Chen (2013), who demonstrated that embodiment enriches mental representations and results in superior later recall with a comparison of free and cued immediate recall and delayed free recall of action phrases that were either memorised with a congruent motor action (embodied condition) or without this action (non-embodied condition). A language related example is that of Hauk, Johnsrude and Pulvermüller (2004) who demonstrated, through the use of functional magnetic resonance imaging, that brain activation occurs in the sensorimotor areas associated with performing the actions lick, pick and kick when a participant hears these words. Finally, a literacy related example, using similar methodology demonstrated that visually presenting Roman characters activated the pre-motor zone in the left hemisphere of right-handed students, and the corresponding pre-motor area in the right hemisphere of left-handed students (Longcamp, Anton, Roth and Velay, 2003). These results indicate that representation of letters in the brain is not only visual, but is also based on the sensorimotor experience of writing letters. Together, these studies provide strong support for Barsalou's Perceptual Symbols Systems Account.

Embodied learning. If we consider that embodiment affects the way we process and store information, then it is important to consider its application to learning and

education. Researchers in the embodied cognition approach have some ideas about why embodiment is particularly applicable to the educational context. Lindgren and Johnson (2013) believe that the converging sensory and motor inputs of the embodied approach result in stronger, more stable memories and mental representations. Wu and Shaffer (1987) suggested that the direct experience involved in an embodied approach produces greater cognitive elaboration in the mental representation. Puow, van Gog and Paas (2014) suggested that internalization of the sensorimotor experience results in a richer mental representation because of the increased sensorimotor experience of the embodied approach. An example of this comes from studies of the use of abacuses. Moderately advanced users maintain their calculation proficiency without an abacus by manipulating an internal representation of the abacus (Hatano and Osawa 1983) and those trained on a virtual abacus did not demonstrate the same level of proficiency (Flanagan, 2013). This indicates that the repeated sensorimotor experience of the abacus creates a stronger, richer mental representation.

A final suggestion for why embodiment supports learning is through grounding. Grounding is an aspect of neural processing that could support how sensorimotor experience produces mental representations of concepts (Nathan, 2008). According to Peirce's (see Glenberg et al, 2007) definition of grounding it is the provision of a concrete, tangible stimulus, such as an object or event, to the interpretant to guide and enrich the formation of the mental representation of an abstract concept. Connections to and interactions with the physical environment provide opportunities for grounding.

One way in which grounding can be applied in the educational context is through the use of gestures to accompany communication. Gestures serve to provide or indicate

concrete instances of an abstract concept and have been shown to improve learner comprehension of content and later performance on tasks involving this content (Nathan, 2008). However, not just any gesture is sufficient to assist learning. The gestures that teachers provide, or ask students to engage in, must be structurally or analogically related to the concept. Segal (2011) called this gestural congruency. The necessity for this functional relationship is what distinguishes an embodied instructional approach from others (Lindgren & Johnson, 2013).

Given that the embodied cognition approach is increasingly adopted, it can guide issues associate with education and learning. Knowledge of the mechanisms underlying cognition can support educational practitioners and policy makers in designing learning environments specifically to suit how information is processed. Interventions and learning environments can be constructed to involve functionally related sensorimotor experiences.

Evidence for embodiment in academic intervention studies. There are few interventions that have been designed based on the principles of embodied cognition. However, those that have been designed, show promising results across academic areas. One area in which success has been demonstrated is through analysis of gesture used by both teachers and learners. Alibali and Nathan (2012) have shown, using McNeill's (1992) typology of gesture, that pointing gestures serve to provide grounding for a concept, and representational gestures (including those gestures that directly depict a concept in shape or motion and those that depict this via metaphor) provide motor and perceptual simulations. Alibali and Nathan (2012) are therefore able to argue that mathematical cognition is embodied because it is grounded in the environment and is, at

least in part, based in sensorimotor experiences. They suggested then that mathematics intervention might benefit from including gesture in instruction and encouraging students to gesture. This suggestion was shown to be true in a study where students performed representational gestures for Physics concepts and those that did demonstrated better retention for their understanding of the concept than those who observed the action (Kontra, Goldin-Meadow, & Beilock, 2012).

A reading comprehension intervention has also been designed with embodiment as the key component. Glenberg (2008) believes that one reason children struggle with the symbolic nature of reading is that it lacks grounding. As children learn language skills, many grounding stimuli are typically available in their immediate environment, for example, when initially exposed to the word dog there would typically be a dog, or pictorial representation of a dog, in the immediate environment. The same is not always true when learning to read words. To address this, Glenberg (2011) developed an intervention (Moved By Reading) that involved the physical manipulation of toys, representing the setting and characters in the story, and then trained the students to imagine this manipulation. Findings from these studies indicate that substantial improvements are made to reading comprehension with this intervention and that these gains can generalize to support math word problem solving. Similar effects are demonstrated for both those trained on physical manipulation and those trained on physical manipulation and then imagined manipulation. This indicates that with mastery of physical manipulation the sensorimotor experience can be successfully simulated in imagined manipulation to provide equal benefit.

While these studies provide strong support for applications of the embodied cognition approach as part of academic instruction, they are also rather obvious applications of this approach. There are other areas of instruction where the application of embodiment is less obvious, such as in direct instruction of the alphabetic principle in early literacy education. Keifer and Trumpp (2012), in their review of embodiment, recognise that the grounding of reading in the sensorimotor system is not obvious, but suggest that embodiment theory predicts that the motor and sensory experiences of writing are activated through simulation during reading. Support for this position comes from the previously discussed Longcamp and colleagues (2003) study of handedness and pre-motor area activation with visual exposure to letters.

Further support is found in a study that demonstrated that handwriting training resulted in better letter recognition and spelling in comparison to typewriter training (Cunningham & Stanovich, 1990). Keifer and Trumpp (2012) reviewed a number of similar studies, both with pre-school aged children and with adults, and found that the improved letter recognition extends to discrimination of actual letters from their mirror images. They also elaborated on the functional magnetic resonance imaging studies, indication that motor areas are only activated for letters trained through writing, not those trained through typing.

As well as supporting the position that reading is embodied through handwriting, these studies also support the position that sensorimotor experiences alone are not sufficient to result in embodiment; these experiences must be functionally related to the symbol to be learned. In handwriting, a motor trace that thoroughly defines the shape of the letter to be learned is made, elaborating on the mental representation of the symbol

and leaving behind a unique correspondence between the visual image of the letter and the movement needed to create it. However, this does not occur in pressing a letter key. The movements needed to press a key are not functionally related to the letter target and vary depending on the preceding sequence of key presses (Longcamp, Zerbato-Poudou & Velay, 2005). As a result no relationship is formed between the visual form and movements needed to produce the letter, explaining why there is better learning associated with handwriting. Therefore, in designing an embodied early literacy intervention to provide direct instruction in the alphabetic principle, it should include a movement functionally related to the letter target, i.e. handwriting.

Reframing Multisensory Approaches as Embodied

Our growing understanding of embodiment provides a new lens, through which to look at multisensory literature. While theoretical explanations of multisensory instructional approaches do not stand up to scrutiny, a few of the studies evaluating the efficacy of these approaches have shown success. However, the research designs in these studies tend to be weak, either employing a non-parallel control intervention or a condition that involves some degree of embodiment. With no explanation of these effects, it is possible then that embodiment, rather than the multisensory approach, may provide insights into the effects.

For example, in the recent study by Labatt and colleagues (2015) examining the effects of multisensory and unisensory instruction conditions on the acquisition of letter sound correspondence assessed by pseudoword decoding, their conclusion that multisensory methods are more effective than unisensory methods is questionable based on the methodology employed. Both multisensory conditions in this study (visuo-haptic

and visuo-graphomotor) involved a high degree of functional embodiment and involved very similar motor activation. The visuo-haptic condition involved tracing the outline of the letter shape, in accordance with the convention of the written code, with the index finger. The visuo-graphomotor condition involved writing the letter. At the gross motor level, the motor activity is the same in these two conditions. Both involve the shape of the letter being created by the arm, a functionally embodied action. Given that both conditions were similarly superior to the other, unisensory conditions, it would appear that it is possible that these multisensory interventions are successful because they involve a high level of functional embodiment, not because they are multisensory.

Similarly, if we examine the evaluations by Fernald (1943) and Hulme (1979; 1981), a similar conclusion can be drawn. Fernald's "multisensory trace" method involved looking at a word while tracing the word form with their index finger. His other condition was simply looking at the word. Again the multisensory condition involves a high degree of functional embodiment, as the motor activity involves creating the shape of the letter with the arm, whereas the non-multisensory condition does not involve any functional embodiment. Hulme (1979; 1981) used this technique in comparisons of the effect of multisensory and unisensory training on memory. His conditions required that students either look at sequences of letters (unisensory condition) or look at the sequence of letters and trace the shape of each letter with their index finger. Memory was assessed by asking the children to recall the sequence of letters with which they were presented in the learning phase. Findings indicated that memory for the letter sequence was superior in the multisensory condition, particularly for delayed readers as compared to on track peers. This effect was replicated with non-verbal abstract symbols using the same

teaching conditions and producing the same result in relation to the improved recall in the multisensory condition. These results were originally interpreted to demonstrate that multisensory instruction produces superior recall of letter sequences. However, given the difference in functional embodiment across the multisensory and unisensory conditions, they could also be interpreted to demonstrate that functionally embodied instructional approaches produce superior recall of letter sequences.

More demonstrations of this same effect can be found in the literature. Thorpe and Borden (1985) claimed that multisensory instructional approaches are effective for sight word learning. This conclusion was fundamentally flawed given that it was based on a comparison of a visual-auditory (VA) teaching condition to a visual-auditory-kinesthetic-tactile (VAKT) condition. Both of these conditions are multisensory. In this study the VA condition involved students seeing the word and hearing a teacher recite it before reciting it themselves. The VAKT involved the same activities but added tracing the words with the index finger while saying the sounds in the word, tracing over the words with a pencil while saying the sounds in the word, and underlining the word while reading it. The first two of these activities involve a high degree of functional embodiment, creating a motor trace that is the same as the physical form of the word. The third activity involves non-functional embodiment. Their assessment of the mean percentage of words read correctly by students at the end of each testing session resulted in a clear demonstration of superior recall in the VAKT condition over the VA condition that was replicated in a repetition of this methodology. Therefore, while this study failed to operationalize multisensory/unisensory conditions, it did successfully operationalize functional embodiment (VAKT) and no embodiment (VA) conditions, and their data can

be interpreted to demonstrate the efficacy of functional embodiment components in instruction of sight words.

Campbell and Cooke's (2008) demonstration of multisensory instruction effectiveness on number of pseudoword VC and CVC words read per minute also involved a mixture of functionally embodied activities, and non-functionally embodied activities. In this study the baseline phase involved the *Early Reading Tutor (ERT)* intervention (Gibbs, Campbell, Helf & Cooke, 2006) which involves a series of letter sound correspondence, segmenting, word reading and connected text reading activities where the students are presented with letters and words visually and orally. The Multisensory Additions phase involved adding letter formation on carpet with the index and middle finger of the dominant hand, finger tapping, and manipulation of magnetic letters to the baseline phase intervention. It was clearly demonstrated that a greater number of sounds and words were read correctly per minute in the results of this study. The authors concluded that adding multisensory components to the ERT intervention increased fluency of decoding. However, their design limits the ability to form this conclusion. Again in this study, as with Thorpe and Borden (1985), they are adding multisensory components to an already multisensory intervention and can therefore not conclude that the multisensory aspect of the intervention is related to improvements in decoding fluency. A difference that does exist between their phases is that the Multisensory Additions phase involves a functionally embodied activity (letter formation on carpet) and some non-functionally embodied activities (finger tapping and manipulation of magnetic letters). This means that these results may be better interpreted to demonstrate the efficacy of embodiment components in instruction for fluency of

decoding. As both functionally embodied and non-functionally embodied components were involved in the Multisensory Additions phase, no conclusion can be made regarding their relative efficacy in this intervention.

The cumulative effect of reinterpreting these findings is an indication that there is a need for further research investigating the effectiveness of functional embodiment in early literacy interventions. To examine this appropriately, a study must include all multisensory components, auditory, visual, tactile and kinesthetic, but differ in the inclusion of a functionally embodied component.

Present Study

As there have been limited studies that explored embodiment in academic intervention, and, to my knowledge, there are no studies specifically exploring this in relation to early literacy and acquisition of the alphabetic principle, the present research project is intended to expand the literature and gain valuable understanding on the effect of functional embodiment in early literacy interventions. This study assesses the effectiveness of a functionally embodied early literacy intervention, and determines the relative effectiveness of multisensory (non-functionally embodied) and functionally embodied approaches.

In order to examine the effectiveness of a functionally embodied early literacy intervention, this study uses an adapted alternating treatment design across three participants. Students participate in both a functionally embodied intervention and a non-functionally embodied intervention until they reach mastery on the intervention targets. The study answers the research question:

1. What is the relative effectiveness of a functionally embodied intervention compared to a non-functionally embodied intervention on the acquisition of early literacy skills?

II. Method

Setting and Participants

The present study was conducted in an independent elementary school with an enrolment of approximately 200 students. The school reports having approximately 20-25% of students who are English-language learners.

At this grade level, students are typically able to identify letters and letter sounds, as well as read some familiar words. However, some students have greater difficulty developing these skills than others. Eligible students were nominated by their classroom and learning support teachers due to struggles with phonics and decoding. Nomination was based on the teacher's experience and based on the school's routine progress monitoring data. Two students in Kindergarten and one in Grade 1, (two girls and one boy) were selected as participants for the present study. All three students are English-language learners, two Mandarin speakers and one Spanish speaker. Michael and Pam, the Kindergarten students, were both in the same general education classroom and had no known diagnoses or extra support. Jim, the grade one student, was also in a general education classroom for most of the day but spent approximately 15-20 minutes of the day, 3 days per week, in a resource room receiving individual phonics based support, which continued throughout the study. Following identification, screening assessments were conducted to ensure that students selected would benefit from a phonics intervention.

First, students were assessed using the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman &Kaufman, 2004), which can be used to screen for cognitive functioning. Students with scores more than two standard deviations below the mean were not eligible to participate in the study because they may have required a different

type, or a more intensive, phonics intervention that implemented in this study. Student phonics skills were assessed using an assessment of letter and letter sound knowledge (CORE Phonics); only students who knew between 4 and 14 letter sounds and respond in the “intensive” category for CVC (0-9 correct responses) were accepted to the intervention. This ensured that students were performing at a low enough level to benefit from the intervention and also have enough baseline knowledge to participate in the intervention activities. Students were also assessed with a computerized adaptive test of reading level (aReading); students were required to be performing below benchmark, for that time of year (Winter) and their current grade, on this test to be accepted into the intervention.

Measures

Measures of cognitive functioning and phonics skills were administered to the students as part of the initial screening process, to ensure that students met the inclusion criteria for the present study. During the intervention, phonics word lists were administered and percentage of sounds read correctly were calculated as the primary dependent variable. Finally, at pre- and post-intervention, students also completed an additional measure of broad reading skills.

Cognitive functioning. The Kaufman Brief Intelligence Test, Second Edition (KBIT-2) is a short norm-referenced cognitive measure appropriate for screening the cognitive functioning of individuals aged 4.0 to 90.11 (Kaufman & Kaufman, 2004). The KBIT-2 is reported to have strong evidence for reliability and validity (Bain & Jaspers, 2010). The authors demonstrated this reliability and validity with internal consistency values ranging from 0.86 - 0.96; test-retest reliabilities ranging from 0.76 - 0.93; strong

correlations with other cognitive ability tests, including the original K-BIT, the Weschler Abbreviated Scale of Intelligence, the Weschler Intelligence Scale for Children-Third and Fourth Editions, and the Kaufman Assessment Battery for Children; correlations with a variety of achievement batteries, and patterns of performance across ages and in special populations that match those predicted by theory (Kaufman & Kaufman, 2004). The KBIT-2 takes about 15 minutes to administer and is a commonly used screening measure for cognitive functioning. It was administered to the students before the intervention commenced to determine if they met inclusion criteria.

Phonics knowledge. A survey of letter and letter sound knowledge, the *Consortium on Reading Excellence* (CORE) *Phonics Survey* (Honig, Diamond & Nathan, 1999), was administered as a measure of phonics knowledge at baseline, and following the intervention. It asks students to identify upper and lower case letters and the sounds associated with them as well as decoding CVC words and pseudoword words. The CORE Phonics survey takes approximately 10 minutes to administer. A score is obtained that relates to a benchmark criterion. Park, Benedict, and Brownell (2014) used confirmatory factor analysis to provide evidence for the construct validity of the CORE Phonics, showing that, as intended, it measures alphabetic knowledge and decoding skill. They also provided evidence for the predictive validity of these factors, demonstrating that they predict reading fluency and decoding abilities a year later.

Pseudoword CVC decoding. During baseline and intervention, the primary dependent variable, early reading skill, was measured with first attempt individual phoneme accuracy on pseudoword CVC word lists. Students could read the words sound by sound or read the whole word. The use of pseudoword words eliminates concern for

equivalence of prior exposure to the vocabulary. These word lists were generated using the students pre-identified known letter sounds (from performance on the CORE Phonics test) and the letter sounds that were the target of the intervention (see Table A1). Logical analysis was carried out on the word list to ensure equivalence. This analysis ensured initial consonants were either previously known to the student or were the intervention target, and that there were equal proportions of continuous and stop consonants and equal distribution of these at the beginning and end of these words, as per Wolery, Gast, and Ledford (2009).

Students were scored on their first attempt at reading each phoneme. It was considered a correct response if the word was read correctly or if each phoneme was said correctly on the first attempt. Additional rules for scoring included: students' performance was considered correct if (a) letter sounds were repeated, (b) letter sounds were produced in isolation but out of order, or (c) self corrections to the correct response within 3 seconds were made; and student performance was considered incorrect if (a) insertions were made, (b) blended letter sounds were out of order, (c) words were read correctly sound by sound but then blended incorrectly or (d) self corrections that produce an incorrect response were made.

Broad reading. A measure of broad reading skill, aReading, was administered at baseline and following all intervention sessions. This computerized adaptive test assesses a variety of areas including phonemic awareness, phonics, and comprehension with a multiple-choice item format (Christ et al., 2014). The 30 item test was administered and scored on a laptop with web browser software and requires approximately 10-20 minutes to administer. The scores were then compared to the benchmarks available. This

assessment has promising reliability coefficients (alternate forms reliability 0.71-0.97, internal consistency split half coefficients 0.73-0.99, test-retest 0.42-0.98) and evidence supporting its validity in the areas of content validity, criterion related validity, concurrent and predictive validity.

Procedure

Recruitment and screening. BREB ethics approval and research approval from the district were obtained. Three students who were identified by their teacher as struggling with phonics and decoding, but having knowledge of a minimum of 4 letter sounds were asked to participate in this study. Informed parental or guardian consent, and student assent, were obtained prior to beginning the study. After obtaining informed consent, the three students were screened using the KBIT-2, CORE Phonics and aReading, to ensure that inclusion criteria were met.

Experimental design. The selected students participated in a phonics intervention in an adapted alternating treatments design (Sindelar, Rosenburg, & Wilson, 1985). The independent variable in this study was the level of embodiment in the two phonics interventions. The first intervention involved functional embodiment (the FE condition), and the second, non-functional embodiment (the NFE condition). The primary dependent variable was percentage phoneme accuracy on pseudoword CVC wordlists. Wordlists were randomly assigned to experimental conditions by coin toss. In this design, students acted as their own comparison and following a baseline phase experienced two concurrently implemented phonics interventions (FE and NFE). Individual intervention sessions occurred three times a week, in a quiet area in the school, for approximately 10-15 minutes. In each pair of sessions, an intervention was

randomly selected for the first session (by coin toss) and the other intervention was implemented in the second. Each student participated in both interventions until mastery (100% accuracy on word lists in three consecutive sessions) was achieved. At this point intervention continued for the not yet mastered phoneme with its original intervention. Once the stop criterion was reached, the two interventions were repeated twice more using the same process, but with different target phonemes and word lists, to provide opportunity for intra-subject replication of any basic effect.

Progress monitoring. Student progress in early reading skill was collected at the end of every session using pseudoword CVC word lists. Students attempted to read each word on the lists and were scored on first attempt accuracy of reading each phoneme. Prior to baseline and at a two week follow up, the students were asked to complete CORE Phonics and aReading, to measure progress toward grade level benchmarks.

Baseline. Students participated in their regular classroom programming during baseline phase. Data was collected on their pseudoword CVC word list reading accuracy once for each word list to obtain a baseline.

Phonics intervention. Students received the same three phonics activities in each condition. The interventions include three evidence based phonics activities (Name That Letter/Say That Sound, Which Letter Am I? and Read the Word; Vaughan & Linan, 2004). Both conditions involved phonics instruction with visual and auditory stimuli (letter cue cards and spoken letter sounds) but the NFE condition also included small balls to be tossed back and forth, while the FE condition involved a graphomotor activity (see Table 1). Ball tossing was selected for the NFE condition because it is a common activity in multisensory phonics drills, such as in some Orton Gillingham based

interventions. Both levels of intervention lasted approximately 10-20 minutes and occurred three-to-four times per week, focusing on a phoneme identified as being not known to the student in initial screening.

Name That Letter/Say That Sound. In this activity the interventionist held up a card with the target letter and said, "This letter is *A*. The sound for *A* is /a/." In both conditions the student was then asked to name the letter and then say the sound. In the NFE condition, the student was also asked to toss a ball to the interventionist when providing their verbal response, whereas in the FE condition, the student was asked to write the answer as they respond verbally. If the student responded incorrectly, verbally or in writing, the interventionist provided them with the correct response, in the modality in which they were incorrect, and the item was then repeated once. Additional letter cards with known letters and letter sounds were introduced one at a time until there were a total of 5 cards using a "folding-in" technique that followed the following pattern: 1, 1-2, 1-2-3, 1-2-3-4, 1-2-3-4-5 (McNamara, 2001),.

Which Letter Am I? The interventionist told the student that they will now hear a letter sound, and will verbally respond with the letter name. In the NFE condition, the student was also asked to toss a ball to the interventionist when providing their verbal response whereas in the FE condition, the students were asked to write the corresponding letter as they respond verbally. In both conditions the interventionist first modelled the process, and then verbally provided the letter sounds. The provided letter sounds were the same as the target letter sound and the known letter sounds on the letter cards. Sounds were presented using the same "folding in" technique described above. If the student responded incorrectly, verbally or in writing, the interventionist provided them

with the correct response in the modality in which they were incorrect and the item was then repeated once. The interventionist then moved onto the next letter sound.

Read the Word. The interventionist told the student they would be shown a word on a card and they would first sound out each letter-sound and then read that word fast. The students were then shown a CVC word card and the interventionist modelled the task by saying each sound continuously while pointing to each letter, ("*caaaaaannnnn*"). After sounding out the the word the interventionist read the word fast ("*can*"). The student was then shown 3 regular CVC words, one at a time. If the student did not respond correctly the interventionist reviewed the correct letter-sound correspondance and then repeated the item before moving to the next once a correct response was received. The interventionist provided prompts to sound out or read fast as needed. This activity was the same in both conditions.

Table 1.

Summary of Intervention Components with Differences Across conditions Bolded

Intervention Component	Functionally Embodied	Non-functionally Embodied
Name that letter/Say that sound	The interventionist holds up a card with the target letter and says, "This letter is *A*. The sound for *A* is /a/." **The student is asked to repeat this process of naming the letter and its' sound while writing the letter form.** Cards with the target letter and four known letters are presented, one at a time, using the "folding in" technique.	The interventionist holds up a card with the target letter and says, "This letter is *A*. The sound for *A* is /a/." **The student is asked to repeat this process of naming the letter and its' sound while tossing the bal to the interventionist.** Cards with the target letter and four known letters are presented, one at a time, using the "folding in" technique.
Which letter am I?	Interventionist tells student **to name the letter and write it down when they hear a letter sound.** Students are presented with the target letter sound and four known letter sounds in a folding in technique.	Interventionist tells student **to name the letter and toss the ball to the interventionist when they hear a letter sound**. Students are presented with the target letter sound and four known letter sounds in a folding in technique.

Read the Word	Interventionist tells student to first sound out each letter-sound on a CVC word card, and then read the word fast. Interventionist modelled the activity with one card. Interventionist presents three CVC word cards for the student to read, one at a time.	Interventionist tells student to first sound out each letter-sound on a CVC word card, and then read the word fast. Interventionist modelled the activity with one card. Interventionist presents three CVC word cards for the student to read, one at a time.

Integrity of implementation. I served as the interventionist and worked with all of the students during each phase of implementing the intervention to ensure consistency. The interventionist was trained in the methods of intervention and assessment prior to beginning the study. The interventionist used a procedural checklist to guide implementation during the intervention and marked off each component of the intervention to ensure every aspect of the intervention was implemented. Additionally, all of the sessions were audio recorded and 1/3 of the sessions were reviewed by an independent observer, for integrity of implementation and scoring. Interobserver agreement data was calculated using the following formula: percentage agreement = number of agreements / (number of agreements +number of disagreements) x 100.

The independent observer completed the procedural checklist for the sample of reviewed sessions. A step-by-step score was calculated based on their observation of the required elements of each session. Procedural reliability was 98% for all sessions. The observer also independently scored the progress monitoring measure in the selected sessions. The mean inter-observer agreement across all three participants was 96.2% (range 95.8% to 96.7%).

Data analysis

Data for each student's accuracy were graphed and visually analyzed for differences in trend. Additionally, data for each student's number of trials to mastery was graphed and visually analyzed to compare rate of acquisition across the two intervention conditions. Student performance on CORE Phonics and aReading prior to the baseline and at the two week follow up was also compared to determine if generalized gains in phonics and decoding skills were found.

III. Results

Screening Assessment

All three participants were screened for cognitive ability, phonics knowledge and broad reading skill prior to commencing intervention, results displayed in Table 2. On a measure of cognitive ability all participants scored within two standard deviations of the mean. Jim received a K-BIT IQ Composite of 83, Pam of 86, and Michael of 93. This indicates it is a reasonable assumption that all three participants have average levels of cognitive functioning.

On the CORE-Phonics Survey all participants performed in the Intensive category indicating below benchmark phonics knowledge. Jim knew 14 of 33 letter sounds, Pam knew 19 of 33 letter sounds and Michael knew 9 of 33 letter sounds.

On the aReading assessment all participants performed in an at risk category for broad reading skill. Both Jim and Michael performed in the High Risk (1st percentile) category and Pam performed in the Some Risk (30th percentile) category for broad reading skill.

Table 2.

Summary of Screening Assessment Scores

Student	Grade	Cognitive	CORE-PS	Known Letter Sounds	Unknown Letter Sounds	Target Letter Sounds	aReading
Jim	1	83	14/33 (Intensive)	Consonants: d, f, j, k, l m, p, r, s, t, v, w Long vowels: u Short vowels: o	Consonants: n, x, z, y, c, h, g, b, p Long vowels: e, i, a, o Short vowels: e, i, a, u	Short vowels: e, a, o, i Digraphs: ph, sh	407 (1st percentile, High risk)
Pam	K	86	19/33 (Intensive)	Consonants: s, x, z, j, t, y, c, h, m, r, k, w, f, v Long vowels: e, a Short vowels: i, a, o	Consonants: d, l, n, p, g, b, q Long vowels: a, o, u Short vowels: e, u	Short vowels: e, u Digraphs: sh, th, ch, ph	409 (30th percentile, Some risk)
Michael	K	93	9/33 (Intensive)	Consonants: s, m, k Long vowels: e Short vowels: a, o	Consonants: d, l, n, x, z, t, p, c, h, r, w, g, f, q, v, j, b Long vowels: a, i, o, u Short vowels: e, i, u	Consonants: g, w Short vowels: o, a, u, e	373 (1st percentile, High risk)

Direct Gains

Acquisition of letter sound correspondence. Figure 1 displays the percentage phoneme accuracy on each pseudoword CVC word list probe data for Jim, Pam and Michael across all phases and across three series, each with new target letters and probes. For Jim, baseline accuracy ranged from 40-70% and in two of three series baseline levels were within 5% of each other across conditions. However, on the first series the baseline levels differed by approximately 30% across conditions. In the FE condition Jim consistently was accurate with reading his "known" phonemes and inaccurate with the target phoneme. However, in the NFE condition he was inconsistent with his "known" phonemes, reading them incorrectly sometimes. This weakens the demonstrated effect in this series. There was an increase in accuracy following intervention implementation for both the Functionally Embodied (FE) and Non-Functionally Embodied (NFE) conditions. In each series, Jim met the mastery criterion in fewer intervention sessions with the FE condition than the NFE condition. Jim demonstrated good maintenance at two-week follow up in both conditions, with superior maintenance of learning in the FE condition (FE maintained accuracy of 95-100%, NFE maintained accuracy 80-95%).

For Pam, baseline accuracy ranged from 55-65% and in all three series baseline levels were within 10% of each other. Pam also demonstrated an increase in accuracy following implementation of the intervention phase for both the FE and NFE conditions. In one series Pam met the mastery criterion in fewer intervention sessions with the FE condition than the NFE condition. In the other series, mastery was met in equal number of sessions for each condition. In each series a separation in trend lines is observed that indicates a faster rate of learning in the FE condition across each series. Pam demonstrated good maintenance at two-week follow up in both conditions, with equal maintenance of learning in both conditions (100% accuracy maintained in both replications for both conditions).

For Michael, baseline accuracy ranged from 55-70% and in all three series, baseline levels were within 15% of each other. Michael also demonstrated an increase in accuracy following implementation of the intervention phase for both the FE and NFE conditions. In each series Michael met the mastery criterion in fewer intervention sessions with the FE condition than the NFE condition. For Michael's first intervention session in the third series accuracy was measured at 0%. Michael did not want to participate in the intervention session on this day and progress monitoring was abandoned when he refused. Michael demonstrated good maintenance at two-week follow up in both conditions, with equal maintenance of learning in both conditions (100% accuracy maintained in both replications for both conditions).

Together, there were three within-subject demonstrations for two participants and one demonstration for the third participant of more efficient acquisition of letter sound correspondence in the FE condition than the NFE condition. This assertion is supported by a comparison of the average number of trials to mastery (see Figure 2). On average, mastery was achieved in fewer trials in the FE condition (4.443 trials) than the NFE condition (6.113 trials). This amounts to a 27.32% reduction in trials to mastery.

Additional evidence for superior efficiency of the FE condition is noted. There appears to be greater increases in accuracy after one FE intervention session compared to one NFE session. In 7 of 9 series, the increase in accuracy after one intervention session was superior with the FE condition than the NFE. Additionally, maintenance of learning appeared superior in the FE condition phases. All students maintained 100% accuracy at two-week follow-up from the FE intervention phase but maintenance was inconsistent in the NFE condition. Two students demonstrated some decay of learning at two-week follow-up, only in the NFE condition. Together these trends lend further support to the greater efficiency of the NFE condition.

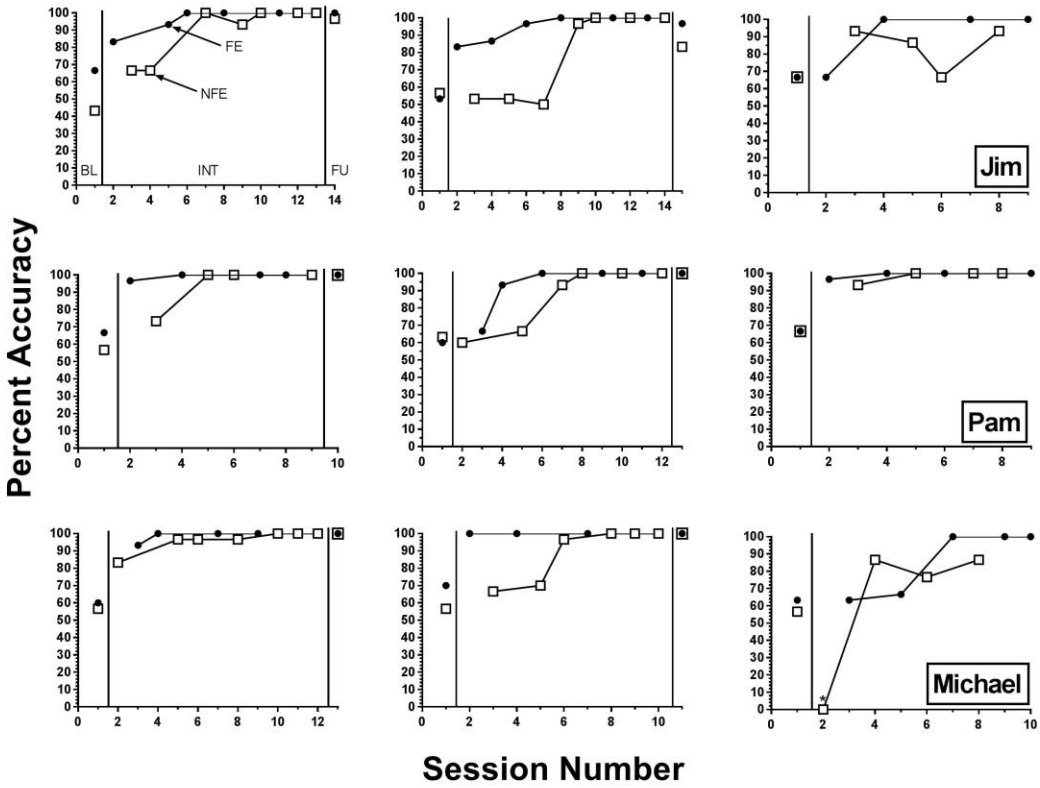

Figure 1. Percent phoneme accuracy of decoding pseudoword CVC words for Jim, Pam and Michael. BL= Baseline phase; INT= Intervention phase; FU= Follow up phase; FE=Functionally embodied intervention; NFE= Non-functionally embodied intervention. * Progress monitoring was abandoned when student refused to participate in the intervention on this day.

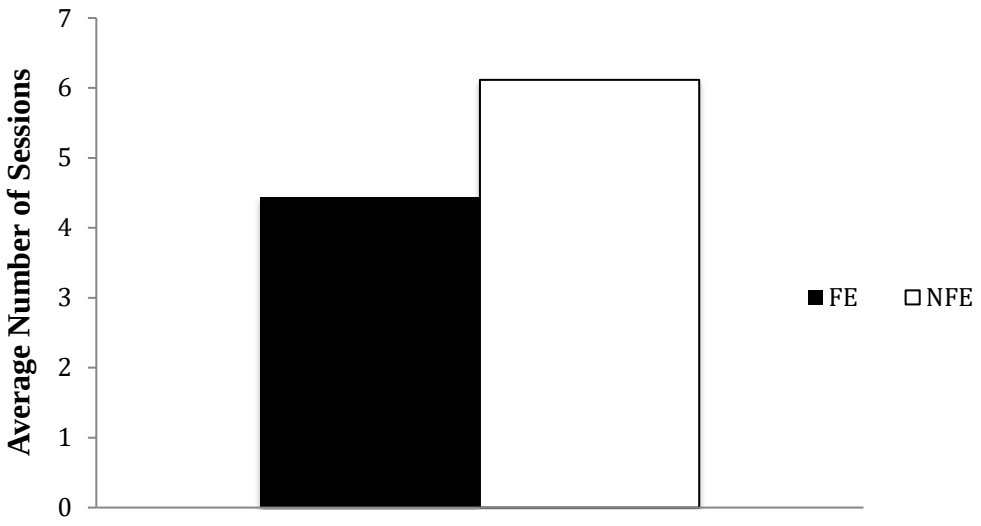

Figure 2. Average trials to mastery of letter sound correspondence. Mastery is defined as 100% accuracy of phoneme reading on pseudoword CVC word lists in three consecutive sessions of an intervention. FE=Functionally embodied intervention; NFE= Non-functionally embodied intervention.

Generalized Gains

Gains in phonics knowledge. A comparison of the performances on the CORE Phonics Survey before and after intervention implementation, shown in Figure 3, indicates improvements in total phonics knowledge for all three participants (Jim knew 14 letter sounds before intervention and 20 after, Pam knew 19 before and 26 after and, Michael knew 8 before and 26 after). Specific improvements are in knowledge of consonant and short vowel sounds, which relate to the targeted letter sounds in the intervention phases.

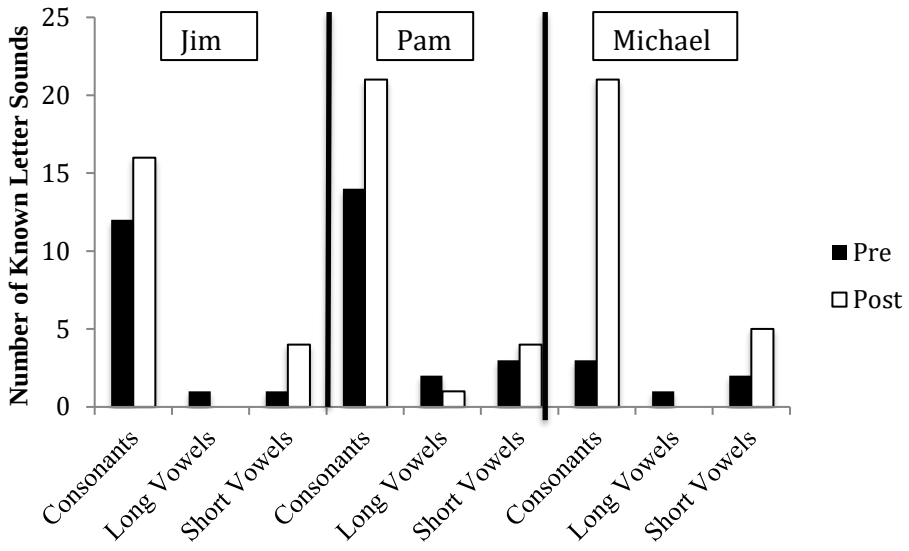

Figure 3. Improvements in phonics knowledge from pre to post intervention for Jim, Pam and Michael, as measures by the CORE-PS.

Gains in broad reading. A comparison of the performances on aReading before and after intervention implementation, using Winter benchmarks, indicates improvements in broad reading skill for all three participants. Jim improved from the 3rd percentile to the 10th percentile, Pam improved from the 34th percentile to the 40th percentile and, Michael improved from the 4th percentile to the 40th percentile (see Figure 4). This equates to an effect size (*d*) of 0.56 for Jim, 0.18 for Pam and 1.43 for Michael.

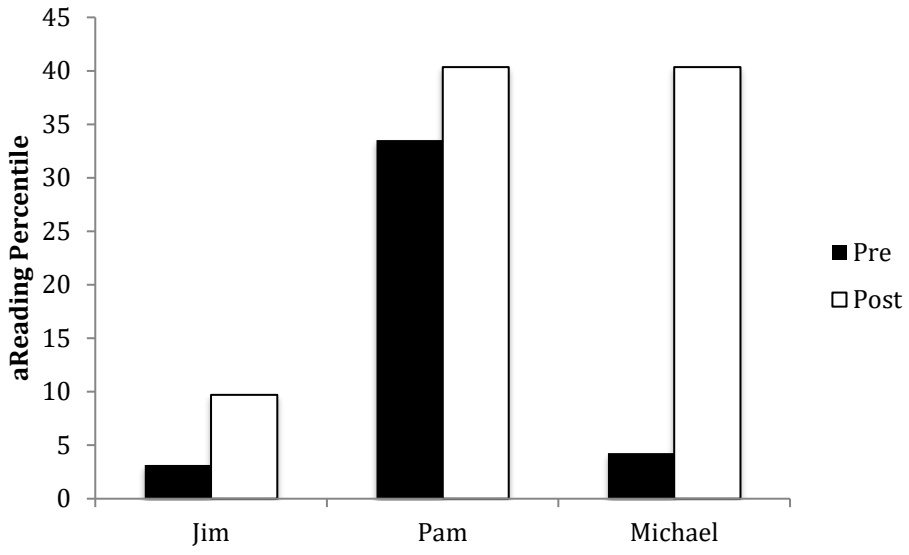

Figure 4. Improvements in broad reading skill from pre to post intervention. Pre and post intervention assessment compared to winter benchmarks.

IV. Discussion

The purpose of the current study was to ascertain the relative efficiency of a functionally embodied vs. a non-functionally embodied (or multisensory) intervention for early literacy skills. It was hypothesized that the instructional procedures in the functionally embodied intervention would require fewer trials to mastery of phonics skills than the non-functionally embodied condition but that both would promote gains on pseudoword CVC wordlists and improve students' knowledge of letter-sound correspondence and broad reading skill. The major findings from this study, limitations, implications and directions for future research are discussed.

Direct Gains

Intervention efficiency was measured by student rate of gains in accuracy on pseudoword CVC wordlists. Encouragingly, and as expected, both visual analysis of the data and an analysis of the mean trials to mastery on the pseudoword CVC wordlists indicated that learning was more efficient in the functionally embodied condition than the non-functionally embodied (multisensory) condition. This effect was replicated in all three series for two students and in one series for a third student. Both Jim and Michael demonstrated 3 clear replications across word lists with differences in efficiency apparent in a reduction in trials to mastery in the functionally embodied (FE) condition. The demonstration is less clear for Pam, who met the mastery criterion sooner once in the FE condition and at the same time in the other two series. However, there is a clear visual trend for a faster rate of learning in the FE condition in each of her series. It appears that Pam's rate of learning was generally faster and this prohibited differentiation in the number of sessions needed to reach mastery, only revealing difference in the trend line. Together the between and within student replications clearly demonstrate superior efficiency of the FE condition.

When visually analysing the gains in pseudoword CVC decoding accuracy an interesting trend emerged regarding improvements after the first session that further supports the superior efficiency of the FE condition. In all but two series both across and within students, gains in accuracy were superior after the first session of FE intervention than the NFE intervention, and the differentiation in efficiency was most evident after the first intervention session. This supports the use of embodied interventions particularly when intervention time is limited.

A second trend was observed through visual analysis of pseudoword CVC word decoding accuracy data. Where two-week follow up data was available, maintenance of learning effects was consistently strong for the FE condition (100% accuracy maintained in all 6 series where data are available). There was less consistency for the maintenance of learning in NFE condition (100% accuracy in 4 of 6 series). This pattern indicates that, for students who had more difficulty retaining their learning, the FE intervention was more efficient due to superior maintenance. Lindgren and Johnson (2013) believe that the converging sensory and motor inputs of the embodied approach result in stronger, more stable memories and mental representations, which would explain this superior maintenance in the embodied condition.

These findings together support the theory of embodied cognition. Specifically, the superior efficiency of an intervention that includes a motor trace that mirrors the visual form of a letter concept in comparison to one that does not, indicates that embodiment, rather than multisensory activation, supports learning (Barsalou, Simmons, Barbey, & Wilson, 2003). It builds on the results of Labat and colleagues (2015), Fernald (1943), Hulme (1979; 1981) and Campbell and Cooke (2008), when reinterpreted with regard to the role of embodiment, in showing that there is a meaningful difference in the development of early literacy skills at the level of individual students between embodied and multisensory conditions. Additionally,

these results add to successful use of embodiment in education in the form of gesture to improve learning of physics concepts (Kontra, Goldin-Meadow, & Beilock, 2012), Glenberg's (2011) Moved by Reading intervention, and superior learning through handwriting rather than typing (Cunningham & Stanovich, 1990). Together these studies provide credence for embodied instructional procedures.

This study expands on the existing literature to create a better understanding of embodied instruction, specifically in the area of early literacy. This study adds to the small body of literature that directly tests embodied instructional approaches and is among the first to do so in the field of early literacy instruction. Further, though Labat and colleagues (2015), Fernald (1943), Hulme (1979; 1981) and Campbell and Cooke (2008) can all be interpreted to support the use of embodiment for early literacy instruction, this study expands on this by purposefully operationalizing "multisensory" and "embodied" from their theoretical basis so that the two can be differentiated and the impact of each be clarified. The clear evidence of superior efficiency of embodied instruction in this study has direct implications for practice, which is highly important given a lack of use of evidence-based interventions has been implicated in failures to support development of literacy skills (Canadian Education Statistics Council, 2009).

Generalized Gains

The experimental design does not permit clear inference about generalized gains because the students were receiving their typical instruction throughout the study. However. generalizability of intervention effect was suggested by increases in phonics knowledge and broad reading skill. There were three improvements in phonics knowledge. Each student demonstrated increases in knowledge of letter sound correspondence on the CORE Phonics Survey from pre to post intervention. Similarly, there were three clear improvements in broad reading skill. Each student demonstrated increased broad reading skill on aReading from pre

to post intervention. This finding adds to a limited body of evidence for generalized gains in studies of both embodied and multisensory interventions. Within this literature, there is a tendency to focus on direct gains. For example Glenberg (2011), in the evaluation of a reading comprehension intervention used primarily reading comprehension and used measures of listening comprehension for those who listened to the stories rather than read them. However, Labat and colleagues (2015) began to explore generalization by adding measures of pseudoword reading and spelling to a measure of letter recognition for a letter recognition intervention and found growth in these areas suggesting the effects of the intervention have generalized. The generalizability findings of this study are in line with those of Labat and colleagues (2015), and further expand on them with a demonstrated effect on broad reading skill. Together they demonstrate that embodied early literacy interventions can lead to gains in generalized literacy skills.

Limitations

There are several limitations worth noting in regards to the measures, sample and intervention procedures employed. The results of this study should be interpreted with regards to the following limitations. First, all intervention and progress monitoring was carried out by a single interventionist. While this procedure reduces the likelihood of interventionist discrepancies, it may allow for bias. The instructor was familiar with the design, objectives and hypotheses of the study and therefore bias may have occurred. While bias effects were largely mitigated by the inter-observer agreement procedure, this limitation must still be considered when considering the results of this study.

Second, the low number of participants in the study limits the generalizability of the results. All of the participants were selected from the same elementary school and all came from families for whom English was not the primary language. The homogenaeity and small size of the group of participants limits the generalizability of the results to other struggling

readers. However, this limitation is typical for single-case design studies, in which generalizability is established through replication. In this study the basic effect was replicated three times for two students and once for the other student. This suggests the findings are rather robust. Further replication of the study would give more evidence to the generalizability of this effect.

Third, the timing of the intervention led to challenges in completing data collection. The third intervention phase for each student ran up until the end of the school year and data collection stopped at the end of the school year when the full design was not yet completed. This means that for two students, the exact difference in efficiency between FE and NFE is not clear in the third series since the intervention ended before the mastery criterion was met in the NFE condition. Additionally, time limitations did not allow for two week follow-up data to be collected for the final intervention series for all three students. Were these data points collected, they may have strengthened any conclusions around differences in efficiency and learning maintenance across the two conditions.

Another limitation relates to the nature of the non-functionally embodied condition. The response format in this condition involved ball tossing during the phonics activities. Ball tossing was selected for the NFE condition because it is a common activity in multisensory phonics drills, such as in some Orton Gillingham based interventions. However, it was observed during the intervention sessions that while students appeared to prefer, and be more engaged with this condition, when compared to the FE condition, it also might have been distracting for them. The ball tossing may have pulled the participant’s attention away from the instructional targets. It is possible that the effects of the increased engagement and the increased distractibility are equivalent, and counter balance each other, but the impact on learning is unclear. Therefore, it would be beneficial to seek a more neutral alternative in future studies.

The final limitation of this study is that the researcher created the word list probes. This was necessary because no standardized probes that were customized to the participant's known and unknown letter sounds were available. Although the researcher strived to create a set of parallell probes by implementing a logical analysis procedure, the probes were not piloted prior to this study. Therefore, it is possible that the wordlists were not of equal difficulty and may have impacted the results. However, the consistency of effect across the three within subject replications, with different probes, for each student suggests that there is low likelihood of the results being related to differences in the word lists.

Implications for Practice

While there have been some studies suggesting that functional embodiment is a facilitator of learning, the body of evidence is small and this study expands on it. Functionally embodied practices have been applied, with success, across a variety of academic domains including reading comprehension, math, physics and study skills (Cunningham & Stanovich, 1990; Glenberg, 2011; Kontra, Goldin-Meadow, & Beilock, 2012). However, this is among the first demonstrations of functional embodiment supporting learning for early literacy skills. This suggests that functional embodiment should be sought when teaching early literacy skills.

Further, this study demonstrated an important differentiation between multisensory approaches and the subset of multisensory approaches that are functionally embodied. Multisensory approaches are those that simultaneously include visual, auditory, tactile and kinesthetic components (Campbell & Cooke, 2008; Moustafa, 1999) and functionally embodied are those whose kinesthetic component involves a movement that it is functionally related to the concept being taught (Lindgren & Johnson, 2013). The results of this study clearly demonstrate that not all multisensory approaches are equal; those with functional embodiment are superior and more efficient when teaching early literacy skills. Therefore it

is important that educators understand the difference between multisensory and functionally embodied approaches and can prioritise functionally embodied early literacy activities over multisensory ones. In practice, this distinction is not widely understood and therefore multisensory approaches have varying degrees of embodiment. For example, the Orton Gillingham (OG) based interventions typically include phonics drills (the student producing the sound of a phoneme when seeing it written on a card), a non functionally embodied activity; and the simultaneous oral spelling activity (student writes or traces letters as they segment and spell an orally presented word), a functionally embodied activity (Gillingham & Stillman, 1997). In OG programs both are emphasized equally despite the evidence for embodied instruction, which could reduce intervention efficiency.

Additionally, given that functional embodiment was achieved in this study just with paper and pencil, functionally embodied approaches may be easier to implement in small group and class wide instruction than multisensory approaches which often can only be implemented in individual instruction due to the need for additional sensory materials. Therefore, embodiment is a more efficient approach to teaching early literacy skills and is also easier to implement and accessible to all students.

Recommendations for Future Research

While the findings of this study lend support to the use of embodiment in early literacy instruction, these findings also highlight the need for further research into the efficacy of embodied instructional methods. This study adds to just a handful of others that have evaluated embodiment in academic interventions (Alibali & Nathan, 2012; Cunningham & Stanovich, 1990; Glenberg, 2011; Kontra, Goldin-Meadow, & Beilock, 2012; Longcamp et al., 2003), which together show a positive trend towards the efficacy of embodied instructional approaches. However, with so few studies evaluating embodied interventions, and each doing so in a different academic area, there is a need for replication and more

evaluation of the efficacy of embodied interventions. More exploration into embodiment in academic intervention is warranted.

Additionally, the successful development and application of an intervention from the theory of embodied cognition, supports the need for more theory-driven intervention development. Hughes (2000) criticized the focus on 'what works' in the field of school psychology without regard for why it works. She postulated that without understanding the mechanisms responsible for change and the specific intervention components that drive change, it is difficult for practitioners to implement interventions and make informed decisions about required modifications. Hughes recognises that, comparatively, school psychology intervention research is much more theory-driven now, but that there is a long way to go to narrow the gap between the science of theory and the practice of intervention (Hughes, 2015). This study provides an example of how an intervention can be developed from theory and through doing so clarifies the specific components that lead to change. Therefore, it highlights the need for more theory-driven intervention research in the field of school psychology.

Conclusion

In support of the superior efficiency of functionally embodied instructional approaches compared to multisensory approaches, a reduction in the trials to mastery with the functionally embodied approach was observed. Thus, students were quicker to learn letter sounds through an embodied approach compared to with a multisensory approach. Students also demonstrated better maintenance of their learning at two-week follow-up with the functionally embodied approach. Generalized gains in broad reading skill and phonics knowledge were observed in both conditions. Despite some limitations in the current study, an embodied instructional approach for early literacy skills, such as the one profiled in this study, has the potential to enhance the reading skills of struggling readers. Future studies

could explore further applications of embodiment in academic interventions or evaluate interventions developed from other cognitive theories. It is hoped that this study will help educators to support students in developing literacy skills, by being informed of the intervention components that drive change.

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Apendix A: Pseudoword CVC Wordlists

Table A1.

Pseudoword CVC Wordlists Used for Progress Monitoring

Student	Series 1				Series 2				Series 3			
	Functionally Embodied		Non-functionally Embodied		Functionally Embodied		Non-functionally Embodied		Functionally Embodied		Non-functionally Embodied	
Jim	tek	sej	saj	lak	cik	cof	yol	yot	phek	phej	shek	shej
	jek	tem	ras	maf	cev	com	yof	yev	phes	phet	shes	shef
	sel	kel	taf	kas	cej	col	yej	yek	phem	phak	shem	shak
	fes	sem	taj	jat	cis	cek	yim	yis	phaj	phas	shet	shaj
	ret	fer	ral	lam	cim	ciz	yif	yin	phaf	pham	shas	shaf
Pam	muf	rus	tek	jek	shek	shej	thek	thaj	chem	chot	phom	phut
	suj	lut	sef	fes	shas	shaf	thum	thef	chas	chak	phes	phek
	tuf	kus	ret	sej	shij	shis	thot	thos	chuj	moch	phaj	meph
	tuj	juk	tem	kez	shom	shoj	thif	tham	tach	kuch	toph	kaph
	rul	lum	sem	fen	shus	shuk	thuj	thit	sach	jech	seph	japh

Michael	tos	tom	koj	moj	wat	wam	nat	nam	suj	luf	tek	jek
	kat	kot	kaj	maj	wak	wom	nuk	nom	rus	muf	sek	seg
	mot	sot	saj	jok	wos	maw	nus	san	tuk	kus	tew	sej
	tok	tak	jom	jos	kew	taw	ken	ton	tuj	juk	tem	kel
	tam	tas	jak	jas	tew	kaw	kun	tun	rul	lum	sem	jem