Increased Complexity in Bidirectional Naming Stimulus Control Enhances Reading in First Graders

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Abstract

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In 2 experiments, I studied the effects of the establishment of Incidental Bidirectional Naming (Inc. BiN) for unfamiliar stimuli on reading comprehension for first-grade students. In Experiment 1, I measured the associations, differences, and predictive value between multiple measures of reading comprehension and Inc. BiN stimulus control in 22 first-grade students. Inc. BiN stimulus control was measured with familiar and unfamiliar stimuli and partitioned into groups according to degrees of Unidirectional Naming (UniN) and Inc. BiN. Measures of reading comprehension included *the i-Ready® K-12 Adaptive* Reading Diagnostic and *Woodcock-Johnson® Tests of Achievement* (*WJIV®*). Results indicated significant correlations between degrees of UniN for unfamiliar stimuli and reading comprehension. In Experiment 2, I studied the effects of the establishment of Inc. BiN for unfamiliar stimuli on multiple measures of reading comprehension in a single case, multiple probe design across dyads. I selected 3 dyads of first graders who textually responded at or above grade-level and demonstrated the absence of Inc. BiN stimulus control for unfamiliar stimuli. There were 3 reading comprehension measures: (1) explicit reading comprehension probe after reading a fiction and nonfiction passage, (2) read-do probe consisting of unfamiliar stimuli, and (3) *WJIV®* subtests. Participants acquired Inc. BiN stimulus control for unfamiliar stimuli through a Multiple Exemplar Instruction (MEI) intervention across listener and speaker responses. After participants demonstrated Inc. BiN stimulus control by emitting at least 80% accuracy across listener and speaker response topographies across two consecutive novel stimuli sets, I assessed reading comprehension performance. Results from experimenter-derived passage comprehension probes demonstrated increases across all 6 participants. Although read-do results were inconsistent, 5 participants demonstrated increases following the acquisition of Inc. BiN stimulus control. *WJIV*® results demonstrated the greatest increases in Passage Comprehension performance, while marginal and educationally significant increases were still observed across Reading Vocabulary and Reading Recall subtests.

Keywords: Bidirectional Naming, bidirectional operants, reading comprehension, relational responding, stimulus relations, vocabulary

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Dedication

"*We shouldn't teach great books; we should teach a love of reading.*"

- B. F. Skinner

To my mom, for teaching me a love of reading, a compassion for helping others, and the confidence to succeed in all my aspirations.

Chapter 1: Introduction & Review of Literature

Introduction

Reading achievement in early elementary education is a strong predictor of future academic success (Lesnick et al., 2010). At that phase of development, a child's reading education shifts from "decoding words" (i.e., see printed word and say the word, or textually responding) accurately and fluently to "reading to learn" by fourth grade (Annie E. Casey Foundation, 2010). Therefore, it is necessary to not only learn to respond fluently to text, but also to comprehend as a means to access general education curriculum. In 2001, the National Reading Panel (NRP) released a research-based report on effective reading instruction in multiple domains: phonological awareness, phonics, fluency, vocabulary, and reading comprehension. In 2019, the National Center for Education Statistics reported that 65% of fourth-grade students performed below proficient levels of reading, indicating a 4% decrease compared to fourth-grade students in 2002. This suggests that over a span of 18 years since the NRP's 2001 report, students continue to demonstrate difficulties in learning to read despite research across many disciplines dedicated to bridging the gap between students performing below grade level and those performing on or above grade level.

According to the National Reading Panel (2001), there are five techniques in effective reading instruction: (1) phonemic awareness, (2) phonics, (3) fluency, (4) vocabulary, and (5) reading comprehension. Vocabulary refers to words an individual must have in repertoire to communicate across all domains, including listening, speaking, reading, and writing (Armbruster et al. 2001; Paul & Wang, 2012). A strong vocabulary repertoire helps create relationships among objects and events in the environment through print stimuli (Goswami, 2000). According to Kamhi and Catts (2012), comprehension involves processes to derive meaning from text to demonstrate an understanding of what has been read. Comprehension includes the prerequisite skills of fluent decoding paired with background knowledge and language understanding. Catts & Kamhi (2017a) argued that reading comprehension varies among individuals depending on the text presented, reading ability, and task required. An example of this variability in reading comprehension is when considering readers' content knowledge. Individuals with a weaker textual responding repertoire can comprehend better than stronger textual responders due to a stronger repertoire of background knowledge (Recht & Leslie, 1988).

While the above evidence is valid, the science of behavior offers additional research that demonstrates how reading comprehension develops as a function of complex language development and a network of novel and previously learned experiences.

Skinner and Reading Comprehension

O'Donohue and Ferguson (2001) argued that Skinner's (1957) use of "understanding" is synonymous with language comprehension. Skinner proposed two views of comprehension – simple and complex. With simple comprehension, a speaker emits a response and the listener emits that response with point-to-point correspondence, thereby "hearing" the message of the speaker. With complex comprehension, the listener emits behavior that mediates the behavior of a speaker. The listener thus demonstrates that they are under the control of the speaker's verbal antecedent. For example, if the speaker provided the antecedent, "Close the door," then the listener demonstrates comprehension by closing the door. A listener also demonstrates complex comprehension when they emit a conditioned emotional response. This type of comprehension response is less direct and observable and therefore the speaker is required to infer whether the listener comprehended their behavior or not. For example, a student is given feedback from a teacher and applies that feedback. An individual can demonstrate comprehension through different forms – under the control of spoken or textual stimuli or under the control of non-vocal or intraverbal stimuli. When the listener's responses are under the control of textual stimuli, then they are a reader, as Skinner (1957) argued that a reader repertoire is an extension of the listener repertoire.

Abstraction

Skinner (1957) identified abstraction as a process of extension, where a verbal response is reinforced in the presence of stimuli that share the same properties. Thus, the stimulus acquires some degree of control over the response. When the property appears in other combinations, that control continues to exert itself over the behavior. Researchers and instructors can sharpen stimulus control by reinforcing responses in the presence of specific stimulus properties and punish responses under the control of unspecified properties. Abstraction is also known as essential stimulus control. Engelmann and Carnine (1982) demonstrated the effects of an MEI intervention on the acquisition of textual responses to novel words, in other words, teaching abstraction through the formation of untaught operants (i.e., words) by joining multiple forms under the same stimulus control. Abstraction is necessary for reading comprehension because the reader is exposed to stimuli that share properties with other stimuli. Thus, the reader can emit a variety of responses through abstraction because of a history of differential reinforcement of responding to stimuli with similar properties across irrelevant dimensions.

Bidirectional Naming

Around the age of two, there is an "explosion" in language, in which typically developing children acquire language at a significant rate, which behavioral researchers attribute to the emergence of the verbal behavior developmental cusp that is a new learning capability of Bidirectional Naming (Hart & Risley, 1995; Greer & Longano, 2010; Greer & Ross, 2008; Greer

& Speckman, 2009). Horne and Lowe (1996) introduced Naming as a bidirectional and circular relation between listener and speaker behavior such that when a child attends to stimuli and, after hearing another tact the stimuli, can acquire novel speaker and listener responses without direct instruction. Greer and Ross (2008) identified Naming as a verbal developmental cusp that is also a new learning capability, meaning that once acquired, a child can contact reinforcement and learn in new ways that they could not before (Rosales-Ruiz & Baer, 1997). Miguel (2016) argued for the use of the term, Bidirectional Naming (BiN) to describe the joining of the listener and speaker repertoires to more accurately reflect the bidirectionality of this relation as originally proposed by Horne and Lowe (1996).

For children with disabilities, interventions may need to be implemented to induce various degrees of BiN stimulus control when it does not develop naturally. These interventions function to strengthen the degree of stimulus control for the establishment of word-object relations from contact alone. Multiple Exemplar Instruction (MEI) across listener and speaker responses (Greer et al., 2005), auditory matching (Speckman-Collins et al., 2007), and Intensive Tact Instruction (ITI) (Pistoljevic, 2008) have been used to induce Bidirectional Naming in children with language delays. Lo (2016) used a repeated probe procedure to induce Bidirectional Naming for familiar and non-familiar stimuli. Kleinert (2018) extended these results by using a repeated probe procedure until mastery of a novel set in a single Naming Experience (NE). She used sets of mixed stimuli that consisted of both unfamiliar and familiar stimuli and found that Bidirectional Naming for unfamiliar stimuli emerged regardless of the use of familiar or unfamiliar pairings.

Development of Bidirectional Naming

Greer and Du (2015) argued that the development of verbal developmental cusps and capabilities results from the establishment of conditioned reinforcers through experience for typically developing children. Past research has used pairing procedures to condition previously neutral stimuli as reinforcers, resulting in the emergence of verbal or preverbal foundational cusps, such as conditioned reinforcement for faces and voices (Maffei-Lewis et al., 2014), conditioned reinforcement for observing books (Tsai & Greer, 2006), and conditioned reinforcement for two-dimensional and three-dimensional stimuli (Greer & Han, 2015). Greer and Du argued that a child acquires Bidirectional Naming when "attention and speech sounds reinforce attention to the spoken word. Hearing and seeing the object results in the emission of a covert or overt echoic which results in word-object relations" (2010; p. 20). Horne and Lowe (1996) suggested that echoic behavior may be a potential source of reinforcement for the acquisition of Naming such that the emission of an echoic requires an interaction between the listener and speaker repertoires. This has been somewhat supported by experimental analyses and further studies regarding the conditioning of auditory and visual stimuli (Longano 2008; Longano & Greer, 2015). However, the last study found that several types of reinforcers for correspondence were in play.

Types of BiN

Two types of Naming identified in the literature include common (C-BiN) and intraverbal (I-BiN) (Miguel, 2016). Common naming refers to acquiring the same name for multiple exemplars of a single stimulus such that the listener and speaker behaviors are within the same stimulus class. Intraverbal naming refers to acquiring word combinations such that the stimuli are evoked by other stimuli. Another type of Naming identified by Miguel (2016) is visual bidirectional naming (V-BiN), in which there is a bidirectional relation between imagining and reacting to covert visual stimuli. Hawkins et al. (2018) categorized Common Bidirectional Naming into two types – Bidirectional Naming (BiN) and Incidental Bidirectional Naming (Inc. BiN). The latter classification (i.e., Inc. BiN) refers to the emergence of untaught listener and speaker behavior following an incidental language experience, whereas BiN refers to the demonstration of a bidirectional operant. They then further classified BiN into three subtypes for each classification for a total of six subtypes: listener, speaker, and joint.

More Complex Forms of Inc. BiN

While much of the research literature has studied the formation of, educational implications of, and source of the basic Inc. BiN capability (i.e., word-object relations), previous research has also demonstrated that more complex forms of Inc. BiN join basic Inc. BiN with additional experiences or interventions and thus, set the occasion for the acquisition of more complex language. Cahill and Greer (2014) studied the acquisition of untaught listener and speaker responses to actions paired with word-object relations (i.e., basic Inc. BiN) through an MEI intervention. Findings from this study suggest that the MEI intervention functioned to join basic Inc. BiN to actions and functions by extending stimulus control to multiple stimuli, which in turn, conditioned observing responses for hearing the auditory stimulus, seeing the visual stimulus (i.e., picture), and seeing the action. Frias (2017) found that more instruction was also necessary for the formation of Inc. BiN stimulus control for other sensory modalities in addition to auditory and visual stimuli. Results implied that, similar to Cahill and Greer (2014), observing responses for tactile and olfactory stimuli required more conditioning to extend stimulus control from basic BiN (i.e., paired auditory-visual stimuli) to another more complex form of Inc. BiN; in this case, other sensory modalities. Additionally, Greer and Du (2015) found that basic BiN can also join other relations by exclusion and that acquiring names by exclusion experience is an extension of Inc. BiN. That is, the formation of word-objects relations through the basic BiN capability transform stimuli not previously presented.

Familiar versus Unfamiliar Stimuli

Lo (2016) and Kleinert et al. (submitted) found that novel auditory and visual stimuli that are similar to stimuli that children previously have had experiences with (i.e., familiar stimuli) are more likely to be acquired as degrees of stimulus control first, while stimuli more remote from children's typical experience (i.e., unfamiliar stimuli) may require additional interventions to extend from familiar to unfamiliar stimuli. Similarly, Cao and Greer (2019) found that children who demonstrated Inc. BiN stimulus control for familiar stimuli in English required additional instruction to extend this stimulus control to stimuli in Chinese. Mosca (2015) also found similar results when comparing degrees of Inc. BiN stimulus control for monolingual English-speaking children and bilingual English and Swedish-speaking children.

Thus, these findings all suggest that there is a continuum of what is familiar (i.e., more easily acquired without direct instruction) to children based on a history of reinforcement for observing and producing, which builds onto the levels of complexity of Inc. BiN. It is possible that this continuum of familiarity changes as individuals build their degree of stimulus control for what is unfamiliar (i.e., correspondence for hearing and saying novel stimuli relations more remote from previous experiences). Previous research on complexity of Inc. BiN stimulus control suggest that other forms, such as actions (Cahill & Greer, 2014), other sensory modalities (Frias, 2017), and exclusion (Greer & Du, 2015)), represent greater complexity because they are more unfamiliar to previously learned experiences and thus require additional intervention to extend stimulus control to these forms. However, it is still unknown in the current research literature when unfamiliar stimuli become familiar as children join novel stimulus relations to previously learned experiences.

Relational Frame Theory (RFT)

Relational Frame Theory (RFT) is an account of language and cognition through a behavior analytic perspective that emphasizes the function and development of language through derived stimulus relations (Hayes, Barnes-Holmes, & Roche, 2001). These relations among stimuli develop without the need for direct instruction (Gross & Fox, 2009). Hayes et al. (2001) defined derived relational responding as “learn[ing] to respond relationally to objects where the relation is defined not by the physical properties of the object but by some other feature of the situation” (p. 25). Therefore, the relational response is under the control of contextual cues rather than formal similarities among the stimuli. In other words, individuals learn to arbitrarily apply relational responses to stimuli based on an instructional history of differentially reinforcing contextual cues to respond in this way.

Properties of Relational Frames

There are three qualities of derived relations: mutual entailment, combinatorial entailment, and transformation of stimulus function. Mutual entailment refers to a relation derived between two stimuli after being taught a unidirectional relation. For example, after being taught A→B, an individual can establish a bidirectional relation (i.e., B→A). Combinatorial entailment refers to deriving a relation between two instances of mutual entailment. For example, an individual, after being taught two instances of mutual entailment (i.e., A→B and A→C), can demonstrate the untaught relation (B→C). Furthermore, the establishment of these relations suggest that the function of each stimulus transfers based on the derived relation established. Using the example from above, if an individual demonstrates an untaught relation (B→A), such that, perhaps, B is opposite of A, and A is a conditioned reinforcer, then, with no direct training, B may acquire conditioned punishment qualities. Thus, stimuli can acquire functions due to untaught participation in verbal relations with other events (Gross & Fox, 2009).

Inc. BiN and Relational Frame Theory (RFT)

Horne and Lowe (1996), in their proposal of Naming theory, argued that the bidirectional relation between listener and speaker behaviors could establish or strengthen stimulus equivalence relations. They suggested that during the training procedures of two relations, the individual emits echoic responses for the stimuli that could possibly train the two stimuli names under one name. In other words, the individual acquires reinforcement for correspondence between seeing the visual stimulus and saying the name of the stimulus. It can be argued that Relational Frame Theory is an extension of stimulus equivalence by investigating relations beyond sameness and therefore Horne and Lowe's (1996) framework can also be applied here as well, as the joining of the listener and speaker repertoires is a relational frame.

Barnes-Holmes et al. (2000) described "derived naming," an early stage of language development in which a caregiver tacts a stimulus in the environment and reinforces a child for orienting towards that stimulus. The caregiver may also ask that the child emit a tact response for the stimulus and in response, model and reinforce the appropriate tact response. They speculated that multiple exemplar training establishes this generalized operant response class of "derived naming," in which this class comes under the control of specific contextual cues. They regard this as "one of the earliest and more important relational frames" (p. 70). This description draws comparisons to Horne and Lowe's (1996) definition of Naming by which a child hears a caregiver tact a stimulus in the environment and can later emit untaught speaker and listener responses when presented with that stimulus. Research in Verbal Behavior Development Theory (VBDT) found that MEI as well as other interventions did result in Inc. BiN (Greer et al., 2005).

Morgan et al. (2020) analyzed the relations between the presence of Inc. BiN and the establishment of relational responses for arbitrary and non-arbitrary stimuli in two experiments. In the first experiment, the experimenter found that there was a significant positive correlation between the degree of Inc. BiN for unfamiliar stimuli and arbitrarily derived relations. In the second experiment, the experimenter analyzed the relationship between Inc. BiN and two types of arbitrary derived relations: visual-visual and auditory-visual. She found that there was a statistically significant difference between the establishment of visual-visual relations and auditory-visual relations, suggesting that auditory-visual relations are more correlated with UniN. Thus, the joining of the speaker and listener repertoire that occurs upon the emergence of Inc. BiN (i.e., a more complex level of stimulus control than UniN) may be necessary for the establishment of more complex derived relations, such as visual-visual relations.

Friedman (2020) studied the relation between degrees of Inc. BiN stimulus control and relational responding in preschoolers and Early Intervention students with and without disabilities. She found that other arbitrarily applicable relations emerged as a function of the strengthening of degrees of Inc. BiN stimulus control for familiar stimuli. The results suggest that the reinforcement value of correspondence between auditory-visual stimuli (i.e., see visual stimuli, say auditory stimuli), as demonstrated in Inc. BiN stimulus control, set the occasion for more complex verbal repertoires in the form of other untaught language relations.

Significance of Inc. BiN

Once a child acquires Bidirectional Naming, his/her rate of learning increases significantly as the stimuli select out his/her responses during instruction. Miguel (2018) argued that Bidirectional Naming, and therefore the establishment of the speaker-as-own listener repertoire is required for verbal mediation – a chain of behaviors that fall on an overt-covert spectrum that is involved when problem-solving. Moreover, research has suggested that the presence of Inc. BiN is associated with greater academic success and performance in general education classrooms (Greer, Corwin, & Buttigieg, 2011). These results were replicated in a similar study by Hranchuk (2016) and suggest that Bidirectional Naming is a prerequisite for the development of more advanced verbal repertoires.

Verbal Behavior Development Theory and Reading Comprehension

Verbal Behavior Development Theory (VBDT) is an extension of Skinner's verbal behavior theory that emphasizes the joining of the listener and speaker repertoires to become fully verbal (Greer & Keohane, 2006). An individual moves through different stages of development with the acquisition of verbal behavior developmental cusps and capabilities. These stages include listener, speaker, speaker-as-own listener, reader, writer, and self-editor. Learning to first textually respond accurately requires the mediation of a listener to reinforce or correct the emission of phonemes in the presence of textual stimuli. Stimulus control for this behavior results when conditioned reinforcement is established for the correspondence between seeing the textual stimuli and emitting the correct phonemes without the need for another person to act as the mediator for reinforcement.

Reader-as-own Listener Repertoire

Greer and Ross (2008) argued that reading can be an advanced form of speaker-as-own listener that is under the control of print stimuli. Speakers emit intraverbal responses in verbal episodes and a listener mediates the behavior of that speaker by providing reinforcement or punishment for that response. In other words, the mediation of the listener reinforces a relation between spoken words and corresponding stimuli in the physical environment. Mercorella (2017) suggests that when reading, an individual acts as a listener to comprehend their own textual responses while their textual responding is analogous to speaker behavior, which is consistent with Skinner's (1957) position and VBDT (Greer & Speckman, 2009).

Greer and Speckman (2009) suggested a stage of verbal development called the reader-as-own listener, when the reader demonstrates comprehension responses under the control of their own textual responses. Thus, reading comprehension occurs when an individual responds to their own textual responses the way that the writer intended for the reader to respond (Greer & Ross, 2008). When textually responding, an individual attends to visual and auditory stimuli that comprise a stimulus class for the operant. In other words, the reader is hearing themselves textually responding to the printed words and must respond to their own reading as a listener, a demonstration of correspondence between reading and doing. Thus, listener behavior is essential to the reading process, and builds on the bidirectional operant of speaker-as-own listener behaviors.

Mackey (2017) studied the effects of a reader immersion protocol on the establishment of read-do correspondence for kindergarten and first grade students. Read-do correspondence refers to reader-as-own listener behavior involving seeing and saying print stimuli (i.e., textually responding) and then performing as a listener to their own textual responses. In other words, it is the formation of behavior under the control of written directions. Following a reader immersion protocol, she found that participants' listener repertoire joined stimulus control for print stimuli through read-and-draw and read-and-build tasks.

Alsharif (2020) modified Mackey's (2017) reader immersion procedure to establish the correspondence between listening to one's own voice and doing (i.e., self-listening), which was measured in two forms: in isolation (i.e., only listening to one's voice) and joined with print (i.e., read-do correspondence). She found that self-listening and self-governance of overt behavior (i.e., speaking and reading aloud) is a necessary component in establishing read-do correspondence and therefore critical in the development of more complex reader-as-own listener behaviors.

Hill-Powell (2015) also studied the relationship between speaker-as-own listener repertoire and the reader-as-own listener repertoire. She found that, although students read faster when reading covertly rather than overtly, responding to their own textual responses as a listener overtly required additional intervention. The experimenter implemented a MEI intervention consisting of responding to comprehension questions when presented with auditory stimuli (i.e., recorded stories) and responding to comprehension questions after covertly reading a text. Results demonstrated that the MEI intervention across hearing others and hearing themselves functioned to join the speaker-as-own listener repertoire to covert textual responding.

Conditioned Reinforcement for Print Stimuli

The reader-as-own listener repertoire develops as reinforcers in the physical environment continue to select out the behaviors of the reader, which ultimately results in the reader coming under the control of the content of the text (i.e., reading comprehension). One of these foundational verbal behavior developmental cusps for reading is the establishment of conditioned reinforcement for observing print stimuli. Tsai and Greer (2006) and Buttigieg and Greer (Submitted, 2020) extended these results by studying the effects of various pairing procedures on conditioning observing responses for print stimuli. Both studies found that rates of acquiring textual responses accelerated following the establishment of conditioned reinforcement for books.

Correspondence for Phoneme-Grapheme and Blending

Once print stimuli and book stimuli select out student's observing responses, students should then start acquiring phoneme-grapheme correspondence, that is, the correspondence between seeing the visual grapheme and vocally emitting the phoneme. Blending instruction involves the emission of these paired phoneme-grapheme responses to form a composite word. Previous research in VBDT focused on phoneme-grapheme correspondence for words with CVC (consonant-vowel-consonant) or CCVC (consonant-consonant-vowel-consonant) patterns. Lyons (2014) found that teaching participants to match and select component phonemes to composite words as auditory stimuli and vice versa increased participants' number of correct textual responses and spelling to words with mastered phonemes. Cameron (2018) joined the vocal blending repertoire with phoneme-grapheme correspondence through a behavioral momentum procedure, which systematically taught participants to emit component phonemes for composite word responses. Mellon (2019) similarly established the component phonemes to composite word relationship by implementing a procedure in which participants listened to composite words and vocally segmented that word into composite phonemes. Across all of these studies to establish phoneme-grapheme correspondence, the findings emphasize the importance of listener literacy and the speaker-as-own listener repertoire in the development of reader behavior.

Conditioned Reinforcement for Reading Content

As the students increase their textual responding repertoire, the content of the text must select out their behavior such that the reading content creates an establishing operation for more complex reader-as-own listener behavior (i.e., reading comprehension). Past research has suggested that increasing the reinforcement value of reading content results in improvements in academically related skills (Cumiskey-Moore, 2017; Bly & Greer, submitted; Gentilini & Greer, 2020; Gentilini & Greer, 2021). Cumiskey-Moore (2017) implemented a collaborative shared reading (CSR) intervention that paired peer interactions with reading responses for fifth grade students. Activities in the CSR intervention required the participants to work with a peer to receive reinforcement through an interdependent contingency. Bly and Greer (submitted) extended the results of Cumiskey-Moore (2017) by comparing the effects of a collaborative independent reading (CIR) intervention to a CSR intervention on increasing reinforcement value for reading content and reading comprehension performance. They found that the CIR intervention was more effective in establishing conditioned reinforcement for reading which increased reading comprehension performance. Gentilini and Greer (2020) built upon these findings by implementing a CSR procedure consisting of reciprocal and collaborative reading activities to increase reinforcement value of reading content and reading comprehension performance for second grade students. Gentilini and Greer (2021) compared this CSR procedure when participants were paired with either an adult or peer and found that participants' reading comprehension performance increased at a greater scale when paired with an adult.

Conditioned Seeing

Skinner (1953) defined conditioned seeing as an individual "seeing" stimuli that are not present in the physical environment due to previous Pavlovian pairings with a stimulus it has been reinforced in the presence of previously. In other words, conditioned seeing demonstrates familiarity with an object by connecting a conditioned response in the environment with other events and stimuli based on a pattern of a conditioned reflex. From the other fields, conditioned seeing is analogous to mental imagery. In VBDT, the existing stimuli are part of a previously learned relation in a relational frame (Greer, 2020). Skinner (1957) described conditioned seeing as the behavior of seeing an image within one's own skin in the absence of a visual stimulus such that this private event of seeing the stimulus evokes a response that mediates the behavior of the individual. He provided an example of reading a novel and emitting an emotional response to the text as a result of conditioned seeing. Thus, as an individual reads, previously learned relations between words and visual stimuli are joined to the text, allowing readers to “see” what they hear.

Conditioned seeing is necessary when the text does not contain any pictures. After Mercorella (2017) found that participants who were dependent on pictures to improve their reading comprehension scored significantly lower on reading comprehension tests. She applied conditioned seeing to reading comprehension by testing the effect of the presence of visual stimuli on reading comprehension. She also tested the effects of sequencing and producing narrative components of stories on participants’ responses to comprehension questions for texts without pictures present. Results demonstrated increases in reading comprehension for texts with and without pictures present as well as increases in conditioned seeing responses.

Inc. BiN Stimulus Control and Comprehension

As an individual reads a text for the first time, they learn the name of the stimulus incidentally through the text as a listener and a speaker. That is, they comprehend by acquiring new relations among stimuli as a listener (i.e., reader) and emit corresponding speaker behavior, demonstrating joint stimulus control, or emission of bidirectional operants in repertoire. When Inc. BiN joins print stimuli, the context and content of the text occasions the conditions for bidirectional operants to emerge, in which the content of the text provides name-learning experiences as the individual observes and responds to the text. This content selects out reading behavior as repeated exposures allow a reader to acquire new vocabulary words and increase comprehension (Greer et al., 2005; Longano & Greer, 2015). Thus, an individual’s vocabulary repertoire expands as a result of bidirectional operants acquired through Inc. BiN. Additionally, textual responding and BiN involve similar processes. When exposed to a novel stimulus, an individual observes a visual stimulus and emits the name of the stimulus (i.e., auditory) to acquire word-name-object relations. When reading, an individual observes a visual stimulus (i.e., attends to the print) and textually responds to the print stimuli (i.e., auditory).

Joining Print to Inc. BiN

Past research implemented interventions to join the Naming capability to print stimuli. Lee Park (2005) studied the effects of a MEI intervention on the transformation of stimulus function from Naming to reading comprehension. The experimenter measured acquisition of comprehension by matching symbols to untaught written words and found that following MEI across speaker and listener responses, the participants demonstrated Inc. BiN stimulus control and emitted untaught reading comprehension responses. Results suggested that the demonstration of Inc. BiN stimulus control is responsible for creating joint control between print and verbal functions. Helou-Care (2009) selected participants who textually responded with fluency, but emitted poor comprehension responses and implemented MEI across listener and speaker responses to teach novel operants directly related to reading comprehension probes. Results showed that Inc. BiN emerged as well as increases in correct responses to reading comprehension probes, thereby demonstrating the relation between the tact repertoire for visual stimuli and fluent textual responding. In other words, the students formed a bidirectional relation between tacting visual stimuli (i.e., picture) and textual responses (i.e., tacting print stimuli). Furthermore, she found that students learned new vocabulary words incidentally. Mercorella (2017) suggested that lack of the Naming capability is a result of poor production repertoires, which includes speaking, writing, and drawing.

Relational Frame Theory and Comprehension

Comprehension forms as an individual reads and forms relations between novel and previously learned experiences. Explicit reading comprehension is mutual entailment, demonstrating a bidirectional relation between two stimuli. Explicit reading comprehension questions involve asking questions where the answers are directly stated in the text, such as "Where did the story take place?" or "What happened at the end of the story?" Other examples of mutually entailed relations when reading include retelling (i.e., emitting point-to-point correspondence with previously emitted textual responses), making personal connections to text (i.e., a bidirectional relation between what is stated in the text and personal experiences), and acquiring novel vocabulary (i.e., word-definition or word-object relations) based on what is directly stated in the text.

Implicit reading comprehension, or responses that are derived from the text and not directly stated by the text, requires combinatorially entailed relations, or the generation of text-based inferences. Implicit reading comprehension questions include inferential questions that require the emergence of a network of relations, such as connecting a previous reading experience with the text (i.e., text-to-text connection). Other examples of combinatorially entailed relations that form when reading include: acquiring novel vocabulary based on context clues in the text (i.e., forming bidirectional relations between the textual responses, known vocabulary in repertoire, and the context of the sentence in the text), the establishment of conditioned seeing (i.e., formation of bidirectional relations between textual responding and emotional responses emitted within the skin), and applying background knowledge to transform print stimuli (e.g., I know [A] and the text tells me [B].Therefore, A→B). Traditional education teaches reading comprehension through question-and-answer format (Raphael, 1986), reciprocal teaching (Palincsar & Brown, 1984), and collaborative strategic reading (Klinger & Vaughn, 1998). *Corrective Reading* is a scripted, direct instruction curriculum that trains derived relations through MEI procedures (Engelmann et al., 1999).

Laurent-Prophete (2017) studied whether implicit reading and listening comprehension in the form of deductions is a type of derived relational responding. She argued that derived relations are a core component of comprehension. In two experiments, she tested the effects of *Corrective Reading* on the emission of combinatorially entailed relations and metaphors. Results demonstrated that the curriculum sequence provided by Corrective Reading increased derived relational responding (i.e., mutual entailment) while also improving reading comprehension responses. Thus, the reader must listen to their own textual responses and form novel relations between stimuli presented in text and their own instructional history. In this respect, reading comprehension (i.e., the formation of mutually entailed and combinatorially entailed relations while textually responding) develops as a function of experiences. That is, a history of differential reinforcement under the control of contextual cues occasions the development of these skills (i.e., relational frames).

Rationale for Study

Although fluent and accurate textual responding is a prerequisite to advanced reading comprehension, more explicit reading comprehension skills need to be taught earlier on and possibly at the same time as learning phoneme-grapheme correspondence. Reading research from VBDT suggests that reading comprehension in the early stages of development is a function of when the context and content of the text occasions the conditions for bidirectional operants to emerge, in which the content of the text provides name-learning experiences and the reader observes and responds to the text. Thus, the content selects out reading behavior through repeated exposures in which the reader acquires new vocabulary (i.e., word-definition relations) and increases reading comprehension through the formation of relational frames (Laurent-Prophete, 2017).

Lo (2016) and Morgan et al. (2020) demonstrated that BiN is not an all-or-none phenomenon. Rather, Inc. BiN is a continuum of degrees of stimulus control for the basic verbal developmental cusp of acquiring word-object relations incidentally. More complex forms of Inc. BiN join with additional experiences or interventions, such as actions (Cahill & Greer, 2014), relations by exclusion (Greer & Du, 2015), other sensory modalities (Frias, 2017), additional auditory sounds (Lo, 2016), and unfamiliar versus familiar stimuli (Kleinert et al., submitted). Applying the basic word-object relation to print stimuli sets the occasion for the acquisition of novel words through reading, thereby providing new levels of complexity for BiN that will join with more complex arbitrarily applicable relations to give way to higher level reading comprehension.

Therefore, the current study seeks to compare the differences in strength of stimulus control for Inc. BiN for familiar and unfamiliar stimuli, represented as both a continuum (i.e., degrees of stimulus control) and subcategories of Inc. BiN (i.e., BiN, UniN, and pre-UniN), as referred to previous literature, on reading comprehension for first grade students.

Research Questions for Experiment 1

Therefore, Experiment 1 sought to answer the following questions:

1. Is there an association between degrees of Inc. BiN for familiar and unfamiliar stimuli and reading comprehension performance?
2. Is there a difference among subcategories of Inc. BiN for familiar and unfamiliar stimuli on reading comprehension performance?

Chapter 2: Experiment 1

Method

Participants

Participants included 22 first-grade students (54.5% male) with a mean age of 6.63 years (*SD* = .38 years) at the onset of the study from a Title I K-2 public elementary school located outside of a major metropolitan city (Table 1). Participants were enrolled in a classroom that used the Comprehensive Application of Behavior Analysis to Schooling (CABAS®) and Accelerated Independent Learner (AIL) models of education, in which behavior analysis was applied to all components of instruction (Greer, 2002; https://www.cabasschools.org/). The majority of participants were White (40.9%), while 22.7% were Hispanic/Latino, 13.6% were Black, 4.5% were Asian, and 18.2% were Mixed/Other. The sample consisted of 5 (22.7%) participants with educational classifications according to their Individualized Education Plans (IEPs). Based on household income, 31.8% of participants were eligible for free/reduced lunch.

At the start of the study, participants' reading level was measured using the *Developmental Reading Assessment, Second Edition®* (*DRA2®*) (Pearson Education, 2006) and the *i-Ready® K-12 Adaptive Reading* Diagnostic (Curriculum Associates LLC, 2017). According to the *DRA®* scores, 18.2% performed below grade level, 36.2% performed at grade level, and 45.5% performed above grade level. According to the *i-Ready®* scaled scores, 0% performed greater than one grade-level below, 54.5% performed less than one grade-level below, and 45.5% performed on or above grade level.

Table 1

Demographic and Academic Information of Participants at the Onset of Study

Measure	*Mean (SD)*	*n (%)*
Age (years)	6.63 (.38)	
Sex		
Male		12 (54.5)
Female		10 (45.5)
IEP		5 (22.7)
Eligible for free/reduced lunch		7 (31.8)
Classified as English Language Learner (ELL)		4 (18)
Race/ethnicity		
Hispanic		5 (22.7)
White		9 (40.9)
Black		3 (13.6)
Asian		1 (4.5)
Mixed/Other		4 (18.2)
DRA® grade level benchmark for first grade		
Below grade level		4 (18.2)
On grade level		8 (36.4)
Above grade level		10 (45.5)
i-Ready Reading grade level benchmark for first grade		
Greater than one grade level below		0 (0)
Less than one grade level below		12 (54.5)
On or above grade level		10 (45.5)

Note. IEP = Individualized Education Program; DRA = Developmental Reading Assessment; Demographic information (i.e., age, sex, IEP, free/reduced lunch status, ELL classification, and race/ethnicity) collected from school database. Free/reduced lunch status is determined from household income.

Setting and Materials

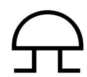
All Inc. BiN probe sessions and administration of the *Woodcock-Johnson*® *Tests of Achievement*, Fourth Edition (*WJIV*®; Schrank, Mather, & McGrew, 2014) took place in the classroom at a rectangular or u-shaped table in a one-to-one setting with minimal auditory or visual distractions. For participants without IEPs, administration of the *i-Ready*® *K-12 Adaptive Reading Diagnostic* took place in a class-wide setting in a computer lab with the experimenter and school interventionist proctoring the assessment. Participants with IEPs took the assessment in the classroom in a two-to-one setting with a teaching assistant proctoring the assessment.

For Inc. BiN probe sessions, we presented target stimuli on Microsoft PowerPoint® presentations. Familiar stimuli consisted of cartoons with non-contrived visual and auditory components that were similar to stimuli that participants likely had prior experience or exposure to (Table 2). Unfamiliar stimuli consisted of symbols with contrived visual and auditory components that the participants likely did not have any prior experience or exposure to (Table 3). The experimenters used pre-constructed data sheets to record data on participants' Inc. BiN responses (Appendix A).

To administer the *WJIV*®, we used Form B of the Standard Battery (i.e., subtests 1-11) and Extended Battery (i.e., subtests 12-20) Test Books. We recorded data on participant responses using the *WJIV*® Form B Test Record.

Table 2

Sets of Stimuli Used for BiN Probes

Familiar Stimuli		Unfamiliar Stimuli	
Auditory Name	Visual Stimulus	Auditory Name	Visual Stimulus
Otto		Naymit	从
Tito		Teesup	≑
Sam		Magoob	円
Regina		Dugle	♋
Lars		Gribat	

Dependent Variables

The variables of interest were degrees of Inc. BiN and multiple measures of reading comprehension. For degrees of Inc. BiN, we measured the acquisition of untaught listener (i.e., point-to) and speaker (i.e., intraverbal tact) responses to novel familiar and unfamiliar stimuli after a single Naming Experience (NE). For reading comprehension, we included domains from the *i-Ready*® *K-12 Adaptive Reading Diagnostic* (Curriculum Associates, LLC., 2017) and *Woodcock-Johnson*® *Tests of Achievement*, Fourth Edition (Schrank, Mather, & McGrew, 2014).

Stimulus Control for Inc. BiN

Strength of stimulus control for Inc. BiN consisted of a categorical measure of Inc. BiN and a numerical measure of Inc. BiN. The numerical measure consisted of degrees of Inc. BiN stimulus control, which was reflective of the strength of stimulus control for acquiring word-object relations (i.e., more degrees of Inc. BiN indicated stronger stimulus control and thus fewer exposures necessary to learn incidentally). Degrees of Inc. BiN stimulus control included the number of correct listener and speaker responses emitted following novel NE across familiar and unfamiliar stimuli. The number of correct listener responses emitted following novel NE represented the degrees of stimulus control for UniN out of 10 total response opportunities. The number of correct speaker and listener responses combined represented the degrees of stimulus control for BiN out of 20 total response opportunities.

Subcategories of Inc. BiN consisted of the following: (1) BiN, (2) UniN, and (3) pre-UniN. The emission of 80% accuracy across both listener and speaker responses demonstrated the presence of Inc. BiN in repertoire. The emission of 80% accuracy across listener responses demonstrated the presence of UniN in repertoire. If the participant emitted less than 80% accuracy across both response topographies, then the participant demonstrated pre-UniN.

Target stimuli sets consisted of five target operants with multiple exemplars of each target stimulus presented twice. Thus, each probe consisted of 20 trials, with 10 listener trials and 10 speaker trials. Incidental NEs consisted of the five target stimuli presented across four multiple exemplars for a total of 20 exposures.

Listener Responses. To measure the accuracy or presence of untaught listener operants, the experimenter presented the target operant with two negative exemplars and the vocal instruction, “Point to ____” or “Show me ____.” The participant emitted a correct response by pointing to the target operant within 5 s of the vocal instruction The participant emitted an incorrect response by pointing to a negative exemplar or emitting no response within 5 s.

Speaker Responses. To measure the accuracy or presence of untaught speaker responses, the experimenter presented the target operant and the vocal instruction, "What is this?" The participant emitted a correct response by vocally stating the name of the operant within 5 s of the vocal instruction. The participant emitted an incorrect response by stating a name that did not correspond with the target operant or emitting no response within 5 s.

Reading Comprehension

***i-Ready® K-12 Adaptive Reading* Diagnostic Domains.** The *i-Ready® K-12 Adaptive Reading* Diagnostic is a standards-aligned assessment administered in the beginning, middle, and end of the school year to monitor student performance and growth. Measures of reading comprehension from the *i-Ready®* assessment included the following domains: (1) Vocabulary, (2) Comprehension: Literature, and (3) Comprehension: Informational Text (Curriculum Associates, LLC., 2017). Skills assessed in the vocabulary domain include academic and domain specific vocabulary, word relationships, and word-learning strategies. The literature comprehension assesses skills related to fiction texts, including, but not limited to: cause and effect, story elements, retelling/summarizing, making inferences, compare and contrast, and character analysis. Informational comprehension measures skills relating to nonfictional texts, such as fact and opinion, main idea and details, text structure, and author's purpose. Refer to Appendix B for Grade 1 state learning standards related to reading comprehension assessed for the Diagnostic. The *i-Ready®* diagnostic automatically converts the participants' responses into a scaled score ranging from 100 to 800.

***WJIV®* Tests of Achievement Subtests.** The *WJIV® Tests of Achievement* is a psycho-educational assessment that measures academic achievement across the domains of reading, writing, and mathematics (Schrank, Mather, & McGrew, 2014). We utilized the following measures to assess reading comprehension: (1) Test 4: Passage Comprehension, (2) Test 12: Reading Recall, and (3) Test 17: Reading Vocabulary. Test 4: Passage Comprehension assesses responses to identify a corresponding word given a sentence or point to a corresponding picture given a phrase. Test 12: Reading Recall assesses accuracy in retelling a story according to predetermined feature points (i.e., words/phrases directly stated in the text) after covertly reading a short story. Test 17: Reading Vocabulary assesses accuracy in identification of synonyms and antonyms after reading a word.

Procedures and Data Collection

Degrees of Stimulus Control for Inc. BiN

Incidental NE. To provide an experientially controlled simulation of exposure of novel stimuli in naturalistic settings, we presented an incidental NE through presentations of each target stimulus. As the visual stimulus appeared, we simultaneously stated the name of the stimulus as the participant observed the visual and auditory stimulus. If the participant did not observe the operant as the experimenter presented the visual and auditory stimuli, the experimenter pointed to the visual stimulus and re-presented the auditory stimulus. The participant was not required to emit any vocal responses when presented with the paired stimuli. Paired visual-auditory presentations consisted of four exemplars of each target stimulus for a total of 20 presentations for each familiar and unfamiliar set.

Inc. BiN Probe. Following a period of at least two hours, the experimenter assessed the emergence of untaught listener and speaker responses. The experimenter presented all listener trials followed by all speaker trials. A plus (+) was recorded upon emission of a correct answer and a minus (-) was recorded upon emission of an incorrect answer. At the end of each probe session, the number of correct responses out of ten total trials were totaled across each response topography and were coded into degrees of UniN (0-10) and BiN stimulus control (0-20). The percentage of accuracy was also coded into a subcategory of Inc. BiN (i.e., pre-UniN, UniN, or BiN).

Reading Comprehension

***i-Ready® K-12 Adaptive Reading* Diagnostic**. The majority of the participants underwent the *i-Ready® K-12 Adaptive Reading Diagnostic* (Curriculum Associates, LLC., 2017) in a class-wide setting. Participants with IEPs underwent the diagnostic in a small group setting with a teacher assistant and no more than two other students present. Other accommodations participants with IEP classifications received included repeating, clarifying, or rewording directions, reading test items aloud, and frequent breaks. Participants received unlimited time to complete the diagnostic and all participants finished the diagnostic within a one-week period across several 30-min blocks. The assessment was administered on the computer and consisted of multiple-choice questions that became increasingly more difficult and complex as the participant emitted more correct responses. Examples of increasing difficulty include fading out auditory support and longer, more complex passages.

WJIV® Tests of Achievement. The experimenter conducted each subtest in a one-to-one setting. The experimenter presented Test 4: Passage Comprehension for all participants, followed by Test 17: Reading Vocabulary, and then Test 12: Reading Recall. The experimenter conducted the assessment according to the instructions on the test record, stopping the assessment when the participant emitted a predetermined number of incorrect responses. Across each subtest, questions became increasingly difficult and complex as the participant emitted more correct responses.

Results

Associations among Degrees of Naming and Reading Comprehension

Table 3 displays the means, standard deviations, and correlations across study variables. Out of the reading comprehension measures, *i-Ready*® Reading vocabulary and informational comprehension scaled scores demonstrated significant, positive correlations across all degrees of Inc. BiN. Out of the BiN variables, UniN degrees across unfamiliar stimuli and BiN degrees across familiar stimuli had the most significant positive correlations with reading comprehension measures. Degrees of UniN for unfamiliar stimuli demonstrated significant, positive correlations across all reading comprehension measures with the exception of *WJIV*® Passage Comprehension, while degrees of BiN for unfamiliar stimuli demonstrated significant, positive correlations across all reading comprehension measures with the exception of *i-Ready*® Reading literature comprehension. Across all statistically significant correlations among variables of interest, correlations were moderate, ranging from .47 to .63.

Table 3

Means, Standard Deviations, and Correlations among Study Variables for Sample (n=22)

	1	2	3	4	5	6	7	8	9	10
1. UniN Fam	--									
2. BiN Fam	.89**	--								
3. UniN Unfam	.53*	.49*	--							
4. BiN Unfam	.60**	.56**	.91**	--						
5. i-R Vocab	.48*	.55**	.57**	.52*	--					
6. i-R Lit	.47*	.46*	.38	.30	.65**	--				
7. i-R Info	.49*	.59**	.56**	.50*	.79**	.64**	--			
8. WJ Vocab	.50*	.58**	.63**	.01	.76**	.75**	.77**	--		
9. WJ Recall	.39	.58**	.47*	.38	.76**	.62**	.84**	.76**	--	
10. WJ Comp	.29	.39	.48*	.39	.76**	67**	.79**	.78**	.79**	--
Mean	8.55	13.59	6.45	9.77	434.05	438.18	452.91	7.23	12.09	19.05
SD	1.74	4.35	2.63	4.62	54.03	54.57	53.31	5.46	17.30	6.09

Note: Significance levels: * p < .05, ** p < .01; UniN = Degrees of Unidirectional Naming; BiN = Degrees of Bidirectional Naming; Fam = Familiar Stimuli; Unfam = Unfamiliar Stimuli; i-R = i-Ready Reading; Vocab = Vocabulary; Lit = Literature Comprehension; Info = Informational Comprehension; WJ = *Woodcock-Johnson® Tests of Achievement,* Fourth Edition; Recall = Reading Recall; Comp = Passage Comprehension; SD = Standard Deviation

Differences in Mean Values of Reading Comprehension across Subcategories of BiN

Table 4 displays a summary of one-way ANOVA results regarding the main effect of categories of BiN for familiar stimuli on measures of reading comprehension. Results demonstrated significant differences on *i-Ready*® Vocabulary scores ($F(2, 19) = 3.54$, $p < .05$), *WJIV*® Vocabulary scores ($F(2, 19) = 3.59$, $p < .05$), and *WJIV*® Reading Recall scores ($F(2, 19) = 3.54$, $p < .05$). Post-hoc Bonferroni tests indicated that participants with BiN emitted higher *WJIV*® Vocabulary scores ($M = 10.83$, $SD = 6.56$) than participants with Pre-UniN ($M = 3.57$, $SD = 1.99$), $p = .016$. Participants with BiN emitted higher *WJIV*® Reading Recall scores ($M = 25.33$, $SD = 26.67$) than participants with pre-UniN ($M = 2.57$, $SD = 3.99$), $p = .016$.

Table 5 displays a summary of one-way ANOVA results regarding the main effect of category of BiN for unfamiliar stimuli on measures of reading comprehension. Compared to the one-way ANOVA results for category of BiN for familiar stimuli, category of BiN for unfamiliar stimuli demonstrated more significant differences on reading comprehension. Results demonstrated significant differences in all reading comprehension measures except for *i-Ready*® Reading Literature Comprehension scaled scores. Participants with UniN emitted higher *i-Ready*® Reading Vocabulary scores ($M = 478.14$, $SD = 54.03$) than participants with Pre-UniN ($M = 413.47$, $SD = 35.94$), $p < .01$. Participants with UniN emitted higher *i-Ready*® Reading Informational Comprehension scores ($M = 504.29$, $SD = 50.17$) than participants with Pre-UniN ($M = 428.93$, $SD = 35.33$), $p < .01$. Participants with UniN emitted higher *WJIV*® Vocabulary scores ($M = 12.71$, $SD = 4.79$) than participants with Pre-UniN ($M = 4.67$, $SD = 3.64$), $p < .001$. Participants with UniN emitted higher *WJIV*® Reading Recall scores ($M = 25.71$, SD 23.57) than participants with Pre-UniN ($M = 5.73$, $SD = 8.63$), $p < .01$. Participants with UniN emitted higher *WJIV*® Passage Comprehension Scores ($M = 23.43$, $SD = 6.37$) than participants with Pre-UniN ($M = 17.00$, $SD = 4.91$), $p < .05$.

Table 4

Summary of One-Way ANOVA Results across Categories of BiN for Familiar Stimuli

			Sum of Squares	df	Mean Square	F
i-Ready® Reading	Vocab	Between Groups	16642.85	2	8321.43	3.54*
		Within Groups	44660.10	19	2350.53	
		Total	61302.96	21		
	Lit	Between Groups	10445.46	2	5222.73	1.91
		Within Groups	52093.82	19	2741.78	
		Total	62539.27	21		
	Info	Between Groups	15210.39	2	7605.20	3.25
		Within Groups	44469.43	19	2340.50	
		Total	59679.82	21		
WJIV®	Vocab	Between Groups	173.32	2	86.66	3.59*
		Within Groups	458.55	19	24.13	
		Total	631.86	21		
	Recall	Between Groups	1704.77	2	852.39	3.54*
		Within Groups	4577.05	19	240.90	
		Total	6281.82	21		
	Comp	Between Groups	33.97	2	16.99	.43
		Within Groups	744.98	19	39.21	
		Total	778.96	21		

Note: Significance levels: * $p < .05$; *WJIV*® = *Woodcock Johnson*® *Tests of Achievement*, Fourth Edition, Vocab = Vocabulary; Lit = Literature Comprehension; Info = Informational Comprehension; Recall = Reading Recall; Comp = Passage Comprehension; *df* = degrees of freedom

Table 5

Summary of One-Way ANOVA Results across Categories of BiN for Unfamiliar Stimuli

			Sum of Squares	df	Mean Square	F
i-Ready® Reading	Vocab	Between Groups	19964.36	1	19964.36	9.66**
		Within Groups	41338.59	20	2066.93	
		Total	61302.96	21		
	Lit	Between Groups	10487.48	1	10487.48	4.03
		Within Groups	52051.79	20	2602.59	
		Total	62539.27	21		
	Info	Between Groups	27099.46	1	27099.46	16.63**
		Within Groups	32580.36	20	1629.02	
		Total	59679.82	21		
WJIV®	Vocab	Between Groups	309.10	1	309.10	19.15***
		Within Groups	322.76	20	16.14	
		Total	631.86	21		
	Recall	Between Groups	1905.46	1	1905.46	8.71**
		Within Groups	4376.36	20	218.82	
		Total	6281.82	21		
	Comp	Between Groups	197.24	1	197.24	6.79*
		Within Groups	581.71	20	29.09	
		Total	778.96	21		

Note: Significance levels: * $p < .05$, ** $p < .01$, *** $p < .001$; *WJIV*® = *Woodcock Johnson*® *Tests of Achievement*, Fourth Edition, Vocab = Vocabulary; Lit = Literature Comprehension; Info = Informational Comprehension; Recall = Reading Recall; Comp = Passage Comprehension; *df* = degrees of freedom

Discussion

The correlational analyses demonstrated multiple significant positive, moderate relations between measures of degrees of Inc. BiN and multiple measures of reading comprehension.

Degrees of BiN for familiar stimuli and degrees of UniN for unfamiliar stimuli demonstrated the most significant, positives correlations with measures of reading comprehension (Table 3). Degrees of BiN for familiar stimuli demonstrated positive associations with all reading comprehension measures except for *WJIV*® passage comprehension and degrees of UniN for unfamiliar stimuli demonstrated associations with all reading comprehension measures except for *i-Ready*® Reading literature comprehension.

For each reading comprehension measure in this study, participants were required to act as a reader-as-own listener, emitting textual responses and connecting those responses to previously learned relations in various levels of complexity. Therefore, participants who were more likely to emit untaught listener responses (i.e., greater degrees of UniN stimulus control) were also more likely to emit behavior under the control of print stimuli through self-listening (Alsharif, 2020). Out of the reading comprehension measures, domains of the *i-Ready*® Reading diagnostic had the most significant correlations with measures of Inc. BiN. The diagnostic requires students to select out an answer out of a field of three or four. Thus, it is possible that *i-Ready*® Reading domains had more significant relations because they required a production responses and participants with greater degrees of UniN were more likely form novel listener relations under the control of print stimuli.

One-way ANOVA results indicated that both an individual's demonstration of Inc. BiN stimulus control for familiar and unfamiliar stimuli can make a significant difference in reading comprehension scores. The post-hoc analyses demonstrated that the significant differences were found between participants with pre-UniN and participants with BiN for familiar stimuli. This suggests that for participants of this developmental stage, it is not enough to induce UniN for familiar stimuli. Rather, it is critical to induce more complex levels of BiN stimulus control (i.e., BiN for familiar stimuli) so that the stimulus control extends to other stimuli (i.e., print, cross-modal senses, etc.). The presence of UniN for unfamiliar stimuli versus pre-UniN for unfamiliar stimuli demonstrated significant differences in more reading comprehension measures than for familiar stimuli. This implies that it is the correspondence between seeing and hearing unfamiliar stimuli and not familiar stimuli that may result in greater success in reading comprehension because unfamiliar stimuli require Inc. BiN stimulus control at a more complex level than familiar stimuli.

These findings are consistent with Morgan et al.'s (2020) findings that degrees of BiN for unfamiliar stimuli demonstrated more associations with measures of derived relational responding, given that Laurent-Prophete (2017) described reading comprehension as relational responding. Thus, students with higher degrees of BiN for unfamiliar stimuli are more likely to demonstrate arbitrarily applicable relational responding, and therefore, apply this type of responding to reading comprehension through their network of novel and previously learned relations.

Rationale for Experiment 2

The results from Experiment 1 suggest that, at the first-grade level, the acquisition of Inc. BiN stimulus control for unfamiliar stimuli is a significant factor relating to and comparing differences on reading comprehension measures. However, the results do not indicate whether the establishment of Inc. BiN causes improvement in reading comprehension scores. Therefore, the purpose of the second experiment in the current study is to determine how the establishment of Inc. BiN will impact different measures of reading comprehension performance through a single-case experimental design.

The same *WJIV*® subtests from Experiment 1 were used to measure reading comprehension performance in addition to two experimenter-derived measures to further assess mutually entailed and combinatorially entailed reading comprehension. An experimenter-derived passage comprehension measure assessed the mutually entailed, explicit reading comprehension of participants. A read-do probe for unfamiliar, novel stimuli assessed the participant's functional vocabulary repertoire by requiring them to textually respond to novel stimuli and perform a corresponding action with those stimuli.

Experiment 2 will seek to answer the following research questions:

1. Will the establishment of Inc. BiN stimulus control for unfamiliar stimuli improve standardized reading comprehension performance?
2. Will the establishment of Inc. BiN stimulus control for unfamiliar stimuli increase correct, explicit reading comprehension (i.e., mutually entailed) responses in passage comprehension tasks?
3. Will the establishment of Inc. BiN stimulus control for unfamiliar stimuli establish read-do correspondence (i.e., textually respond to print stimuli and perform the corresponding action) for unfamiliar, novel stimuli?

Chapter 3: Experiment 2

Method

Participants

The experimenter selected six first-grade students from a general education inclusion classroom as described in Experiment 1. Assessments conducted prior to or at the onset of the study indicated that all participants textually responded at or above grade-level, according to *DRA2*® scores, and demonstrated at least UniN stimulus control for familiar stimuli. Additionally, participants all demonstrated read-do correspondence for familiar stimuli in preexperimental probes. Participants were selected because they did not demonstrate Inc. BiN stimulus control for unfamiliar stimuli in preexperimental probes. Table 6 displays the degrees of UniN and BiN emitted by participants prior to the onset of the study.

Table 6

UniN and BiN Stimulus Control of Participants prior to the Onset of Experiment 2

Dyad	Participant	Familiar Stimuli		Unfamiliar Stimuli	
		UniN	BiN	UniN	BiN
Dyad 1	1	10*	16	7	9
	2	10*	20**	8*	13
Dyad 2	3	10*	14	8*	12
	4	10*	16	9*	13
Dyad 3	5	10*	16	9*	11
	6	9*	17**	10*	16

Note: One asterisk (*) denotes the demonstration of UniN stimulus control (out of 10 possible opportunities), while two asterisks (**) denotes the demonstration of Inc. BiN stimulus control (out of 20 possible opportunities). Stimuli sets for familiar and unfamiliar stimuli and procedure of preexperimental Inc. BiN probes were conducted in the same method as Experiment 1.

To increase the number of participants that would contact the intervention, the experimenter assigned participants to dyads for the combined pre-post Inc. BiN multiple probe design. *i-Ready*® *K-12 Adaptive Reading* Diagnostic scores, obtained prior to the onset of the study, determined the placement of participants in dyads. Dyads consisted of Participants 1 and 2, Participants 3 and 4, and Participants 5 and 6. Participant 1, 6.66 years old, Participant 4, 6.94 years old, and Participant 6, 6.12 year old, were female. Participant 2, 6.79 years old, Participant 3, 6.75 years old, and Participant 5, 6.46 years old, were male. Participant 2 was classified as an English Language Learner (ELL) and spoke primarily Spanish at home. Participant 2 also had an IEP classification of "Communication Impaired" and received special education services in addition to being eligible for free/reduced lunch. See Table 7 for additional demographic and academic information of participants prior to the onset of the study.

Table 7

Participant Demographic and Academic Information for Experiment 2

Dyad	P	Age	Sex	Race	Eligibility for Free/Reduced Lunch	IEP	DRA Score	i-Ready Reading Grade-Level Equivalents			
								Overall	Vocab	Lit	Info
Dyad 1	1	6.66	F	W	N	N	10	L1	L1	L1	L1
	2	6.79	M	H	Y	Y	10	E1	E1	E1	M1
Dyad 2	3	6.75	M	H	N	N	10	M1	M1	E1	L1
	4	6.94	F	W	N	N	8	K	K	K	E1
Dyad 3	5	6.46	M	W	N	N	6	K	K	K	K
	6	6.12	F	W	N	N	6	K	K	E1	K

Note: P = Participant; Age reflects participants' age in years at the onset of the study; F = Female; M = Male; W = White; H = Hispanic; Demographic information were collected from the school database; *i-Ready*® Reading diagnostic; *DRA2*® scores reflect grade-level equivalents at the onset of the study; Vocab = Vocabulary; Lit = Comprehension: Literature; Info =

Comprehension: Informational; E/M/L correspond to grade level equivalent performance (i.e., L1 = Late Grade 1; E1 = Early Grade 1; M1 = Middle Grade 1)

Setting and Materials

Due to circumstances related to the COVID-19 pandemic, the physical setting varied between the participants' home and the classroom due to switches between virtual and in-person learning as mandated by the district. However, regardless of the physical setting, all sessions took place on *Google Meet*. The participants used materials provided by the school district, including a *Chromebook* and headphones. Across all probe and intervention sessions, participants received backup reinforcers through their class-wide point system for correct responses, when applicable, and for following classroom rules.

Establishment of BiN for Unfamiliar Stimuli Intervention Materials

For the Inc. BiN intervention, the experimenter conducted probes using the *Google Slides* add-on, *Pear Deck, Inc*., and *Google Meet*. For novel NE, the experimenter presented target stimuli to participants via Google Meet on Google Slide presentations. See Appendix D for sample stimuli sets. Each set consisted of five target stimuli. For BiN probes, the experimenter used the "teacher-directed" function of the *Pear Deck* add-on, such that the experimenter could remotely control which slide the participant was viewing, and the "click and drag" response function, such that the participant could click and drag an icon to target stimuli for listener trials. Additionally, the experimenter used preconstructed data sheets to record data (Appendix C).

Reading Comprehension Materials

To measure reading comprehension, the experimenter used both experimenter-derived and standardized assessments. The experimenter administered the *WJIV*® Tests of Achievement used in Experiment 1, read-do probes containing unfamiliar visual and print stimuli, and leveled texts for passage comprehension probes.

Passage Comprehension Probes. Participants read fiction and nonfiction leveled texts on Google Slides presented via Google Meet by the experimenter. See Table 8 for the titles, genres, and levels of texts presented to participants. Texts were categorized to a level according to Pinnell and Fountas (2011) characteristics (Appendix D). The experimenter assigned reading levels to participants based on *DRA2*® scores and classroom data on textual responding accuracy/fluency from the onset of the study.

Table 8

Passage Comprehension Texts for Experiment 2

Level	Set	Genre	Title
F	1	Fiction	Playground
		Nonfiction	Rainforest
	2	Fiction	Parade
		Nonfiction	Dinosaurs
	3	Fiction	Copy Cat
		Nonfiction	Birds
	4	Fiction	Water
		Nonfiction	Musicians
	5	Fiction	Robot
		Nonfiction	S'mores
H	1	Fiction	Cell Phone Santa
		Nonfiction	The Water Cycle
	2	Fiction	The Invitation
		Nonfiction	All About Kangaroos
	3	Fiction	The Birthday Wish
		Nonfiction	All About Magnets
	4	Fiction	Beary and the Three Humans
		Nonfiction	The Apple Life Cycle
	5	Fiction	Ceramic Shop
		Nonfiction	Types of Colors

Read-Do Probes. For read-do probes, the experimenter presented a "Reading Experience" through Google Meet and assigned a Google Slide deck for the probe on the participants' Google Classroom. Appendix E displays sample sets of unfamiliar visual and print stimuli used in read-do probes. While the participant completed the read-do probe, a teacher or teaching assistant was always present, either physically in the classroom or virtually on Google Meet. All target print stimuli were "decodable" in that they all consisted of the following consonant-vowel patterns: CVC (e.g., mig, bap, wuz), CCVC (e.g., flid, brep, traw), and CVCe (e.g., wime, vupe, pote) words.

***WJIV*® Subtests**. All stimuli from the examiner booklet were transferred to Google Slides. The experimenter presented subtests 12 and 17 (i.e., Reading Recall and Reading Vocabulary, respectively) on Google Slides. Subtest 4 (i.e., Passage Comprehension) required selection responses and therefore was presented to participants through the Google Slides add-on, *Pear Deck*, which was teacher-directed and included the "click and drag" function when necessary. To record data, the experimenter used the student test booklet, similar to Experiment 1.

Design

The experimenter used a combined pre-post Inc. BiN multiple probe design across dyads to test the effect of the establishment of Inc. BiN on reading comprehension (Figure 1). The experimenter conducted an initial pre-Inc. BiN read-do and passage comprehension probe at the same time across all participants and then at least two pre-Inc. BiN probes immediately before the implementation of the intervention. Additional pre-Inc. BiN probes were conducted if necessary to ensure steady state responding in baseline. Target stimuli sets for read-do probes and passage comprehension texts were counterbalanced across participants (Table 9).

Measurements for the WJIV® were conducted immediately before entering the intervention and immediately after the establishment of BiN for unfamiliar stimuli. The experimenter counterbalanced the form (i.e., A and B) of the *WJIV®* assessment across participants (Table 9).

Table 9

Assignment of texts, stimuli sets, and forms across all participants for each dependent variable

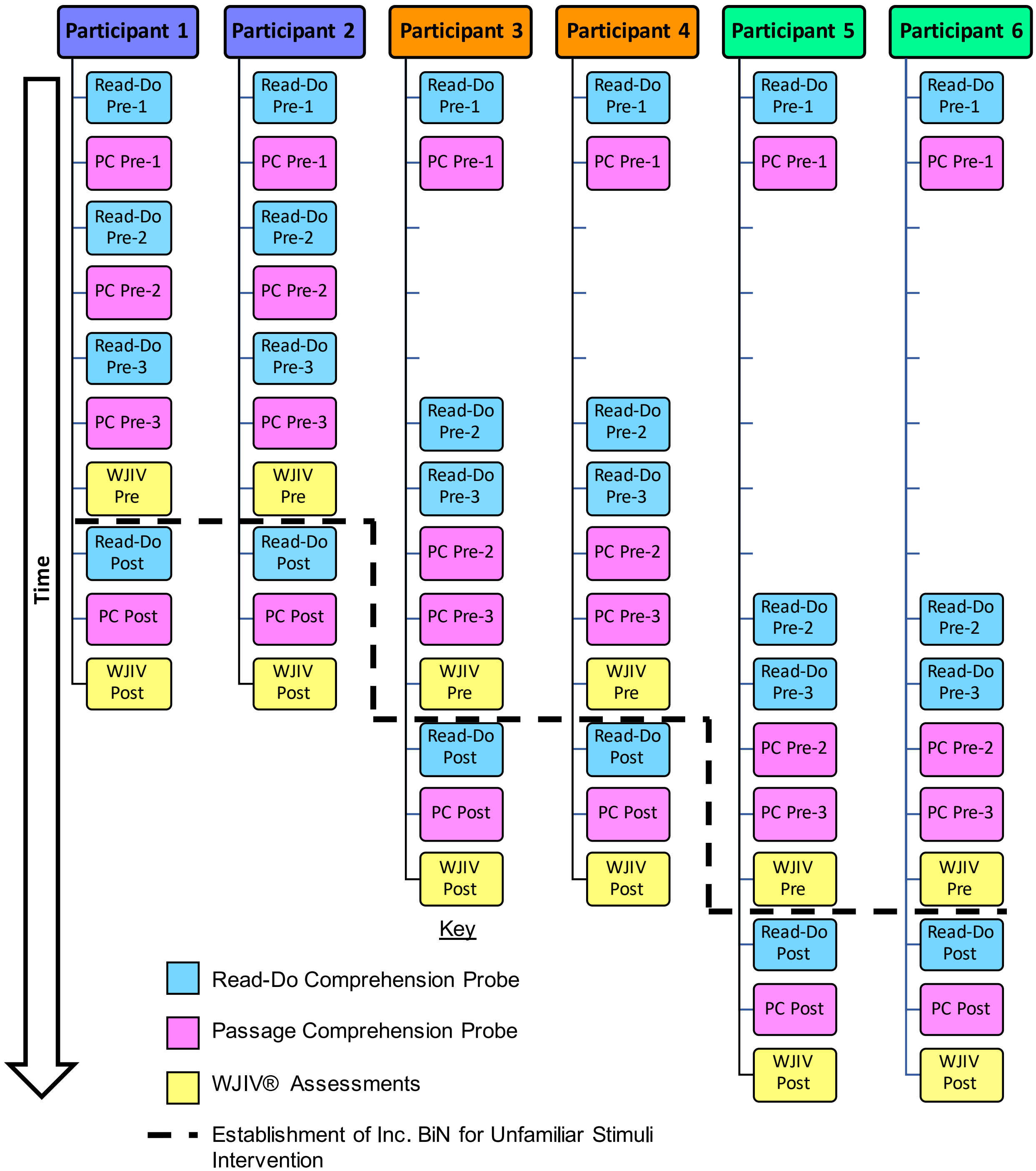
Phase	DV	Participant					
		1	2	3	4	5	6
Pre-Probe 1	PC Text	H3	H4	H2	F1	F2	F3
	RD Set	Set B	Set C	Set A	Set D	Set F	Set E
	WJIV®	Form A	Form B	Form A	Form B	Form B	Form A
Pre-Probe 2	PC Text	H4	H1	H4	F4	F3	F1
	RD Set	Set E	Set A	Set B	Set F	Set D	Set C
Pre-Probe 3	PC Text	H2	H3	H5	F3	F4	F2
	RD Set	Set D	Set F	Set E	Set B	Set C	Set A
Pre-Probe 4	PC Text	H1				F5	F4
Post Probe	PC Text	H5	H2	H3	F2	F1	F5
	RD Set	Set F	Set D	Set C	Set E	Set A	Set B
	WJIV®	Form B	Form A	Form B	Form A	Form A	Form B

Note: PC = passage comprehension; RD = read-do

Multiple probe logic was used to determine the effects of the intervention on the establishment of Inc. BiN for unfamiliar stimuli, while controlling for maturation and history by initiating intervention for the first dyad while the other participants remained in baseline conditions. As each dyad achieved criterion for the intervention and underwent post-intervention probes, the next dyad entered the intervention. Once the participants demonstrated Inc. BiN for unfamiliar stimuli across two novel NE, single Inc. BiN probes, the experimenter conducted post-Inc. BiN reading comprehension measures.

Figure 1

Visual Representation of Experimental Design for Experiment 2



Dependent Variables

The experimenter used a multi-measure approach to assess reading comprehension. Dependent variables of reading comprehension consisted of the following three measures: (1) *WJIV*® Tests of Achievement subtests, (2) experimenter-derived passage comprehension for leveled texts, and (3) read-do correspondence for unfamiliar stimuli.

WJIV® Tests of Achievement

As a standardized measure of reading comprehension, the experimenter implemented the same three subtests from Experiment 1: (1) Test 4: Passage Comprehension, (2) Test 12: Reading Recall, and (3) Test 17: Reading Vocabulary. These subtests were conducted in the same method as Experiment 1, with the exception of the virtual platform as described previously.

Experimenter-Derived Passage Comprehension

Passage comprehension probes consisted of participants answering open-ended, explicit questions (i.e., answers are directly stated in the text) across one fiction and one nonfiction text. Each set consisted of one fiction and one nonfiction text with five different questions presented for each for a total of ten probe trials in a single session. After the participant indicated that they finished reading the text, the experimenter vocally presented five explicit questions and the participant responded vocally to the experimenter. The experimenter did not provide any feedback to the participant. The participant did not have access to the text while answering questions. The experimenter recorded the participant's responses and scored each response as correct or incorrect based on a predetermined scoring rubric. See Appendix G for a sample of the scoring rubric for Set H1.

Read-Do Correspondence for Unfamiliar Stimuli

The experimenter measured functional reading comprehension through the acquisition of novel, unfamiliar vocabulary as demonstrated in a read-do probe. Read-do correspondence is defined as point-to-point correspondence between what is printed and what is emitted by a reader. Each target stimuli set consisted of six novel, unfamiliar visual and print stimuli. The experimenter first presented a "Reading Experience," which provided a simulated experience of exposure to new print stimuli (i.e., word) paired with visual stimuli (i.e., picture). See Appendix H for sample slides from the Reading Experience for Set A. Immediately following the Reading Experience, the participant completed a read-do probe, which consisted of five steps that required the participant to read each step, select the corresponding stimuli, and place the correct color of the stimuli in the correct location as stated in the step (Appendix I). Each probe consisted of ten total target responses: five trials measuring the participants' selection of the correct stimuli, four trials measuring the participants' placement of target stimuli in reference to another target stimulus, and one trial measuring the participants' placement of a target stimulus not directly presented in the Reading Experience (i.e., exclusion response). See Appendix J for a sample (Set A) scoring rubric for read-do probes.

Independent Variable

The independent variable was the establishment of Inc. BiN stimulus control for unfamiliar stimuli. Participants demonstrated Inc. BiN stimulus control for unfamiliar stimuli upon emitting 80% accuracy across both listener and speaker responses across two consecutive single Inc. BiN probes with novel, unfamiliar stimuli (i.e., two different sets of novel stimuli). Target stimuli sets were counterbalanced across each participant within a dyad such that neither participant received a target set of stimuli at the same time. See Appendix K for the assignment of target stimuli sets across all participants.

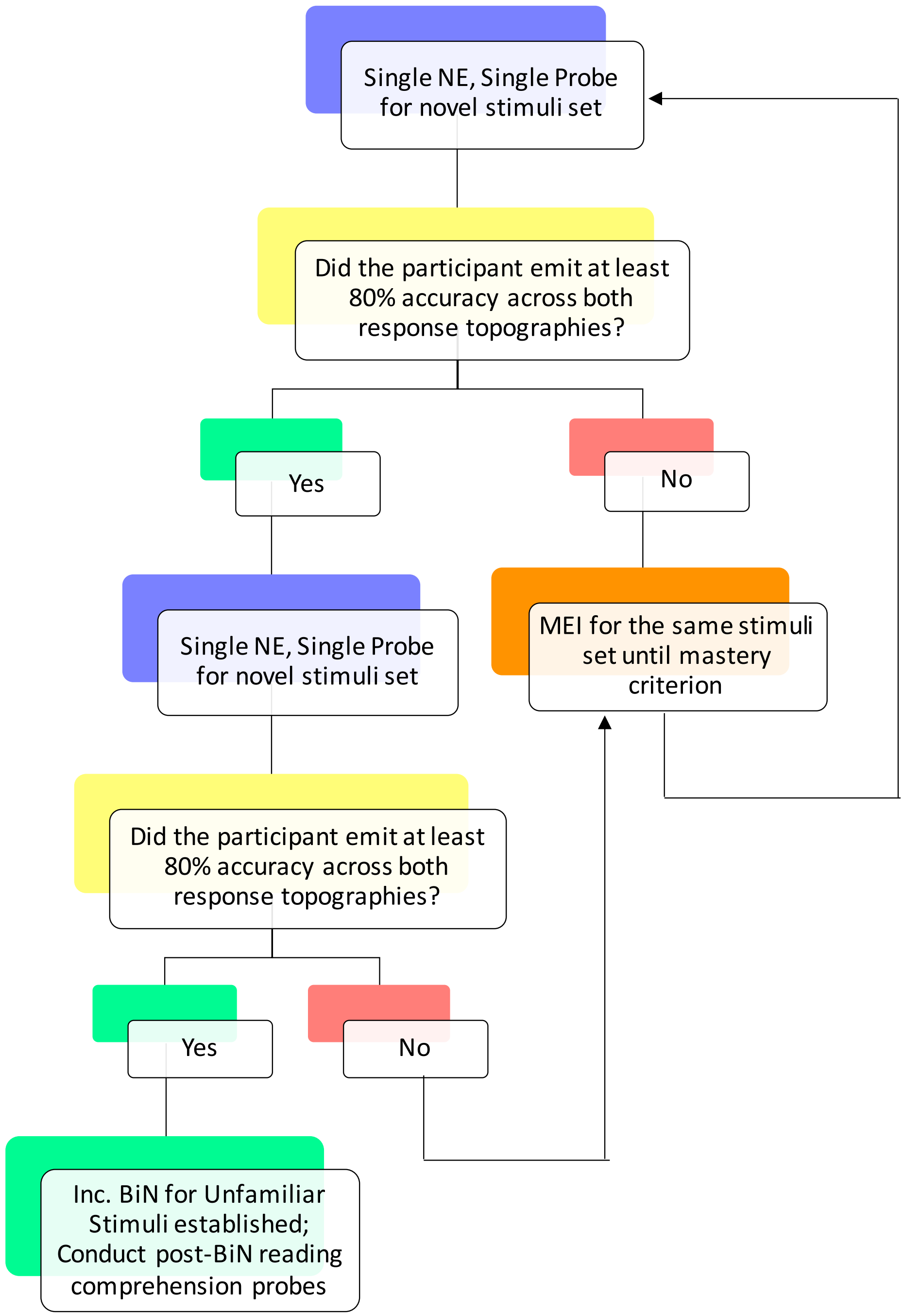
The experimenter first presented a single, novel NE, followed by a single probe for that stimuli set. Single Inc. BiN probes for a novel stimuli set were conducted in the same manner as Experiment 1, with the exception of the virtual platform. If the participant emitted less than 80% accuracy across either listener or speaker responses, then the experimenter implemented MEI across point-to and intraverbal responses for that same stimuli set (Greer et al., 2005). During the MEI phase of intervention, the experimenter rotated presentations of point-to and intraverbal learn units, which differed from probe trials in that the experimenter systematically provided reinforcement or corrections for correct and incorrect responses (Albers & Greer, 1991). Reinforcement for correct responses consisted of vocal praise (e.g., "Very good!") and/or the delivery of points. The correction procedure for incorrect responses consisted of the presentation of the correct response before requiring the participant to emit the correct response independently. Participants received no reinforcement for incorrect responses.

The participant continued to receive MEI across listener and speaker responses until they emitted at least 90% accuracy across both response topographies (i.e., mastery criterion). Following the achievement of criterion, the experimenter then presented a novel stimuli set (i.e., NE for a novel stimuli set), followed by a single probe for that set. If the participant emitted less than 80% accuracy across both response topographies, then the experimenter implemented MEI across listener and speaker responses for that set of target stimuli until mastery criterion. However, if the participant emitted at least 80% accuracy across both response topographies, then the experimenter presented another novel stimuli set and Inc. BiN probe to determine if the participant acquired Inc. BiN stimulus control for unfamiliar stimuli. Any probes with less than 80% accuracy across either response topography resulted in the implementation of MEI across listener and speaker responses for that target stimuli set. This procedure continued until the participant demonstrated Inc. BiN stimulus control for unfamiliar stimuli (Figure 2).

Due to multiple setting events, such as abrupt switches to and from virtual learning, changes in daily school schedule, poor internet connectivity, and new school routines due to the COVID-19 pandemic, the experimenter created a strong motivating operation by delivering a tangible reinforcer (i.e., prize) upon emission of at least 80% accuracy across both response topographies for a single Inc. BiN probe.

Figure 2

Visual Representation of Procedure to Establish Inc. BiN for Unfamiliar Stimuli in Experiment 2



Note: Single Inc. BiN probe for novel stimuli set implies the presentation of a new target stimuli set with a single NE, followed by a probe for that probe. Each time a single NE is presented, the participant is exposed to novel stimuli only one time.

Procedure and Data Collection

Pre-Inc. BiN WJIV® Assessments

The experimenter administered the subtests in the same method as Experiment 1, with the exception of the virtual platform, immediately before the participant entered the intervention. Refer to **Settings and Materials** section for more explanation. The experimenter also collected data on participant responses in the same method as Experiment 1, recording the number of correct responses out of total opportunities and the grade-level equivalent at the end of each session. The experimenter then converted the number of correct responses to standard scores and corresponding percentile ranks.

Pre-Inc. BiN Passage Comprehension Probes

The experimenter first presented the fiction text to the participant and vocal instruction, "You're going to read this story. You can read out loud or in your head (i.e., silently). Tell me when you are done reading the story." The experimenter did not provide any feedback for textual responses. Once the participant provided a signal that they finished reading the passage, the experimenter removed the text from the participant and vocally asked five explicit reading comprehension questions. As the participant vocally responded to each question, the experimenter wrote the participant's response with point-to-point correspondence and compared the participant's response to the predetermined correct response on the rubric. This procedure was repeated for the nonfiction text. The experimenter scored each participant's response based on a predetermined rubric and totaled number of correct responses (Appendix G).

Pre-Inc. BiN Read-Do Probes

Reading Experience. First, the experimenter provided a "Reading Experience" for the set of novel, unfamiliar print and visual stimuli. Each Reading Experience consisted of five target operants consisting of paired print and visual stimuli presented across four exemplars for a total of 20 exposures (Appendix H). The experimenter presented the paired print and visual stimulus to the participant and the participant textually responded to the word aloud. The experimenter provided no feedback for the participant's textual responses. After the participant textually responded to the word, the experimenter pointed to the visual stimulus to ensure that the participant observed both print stimuli and visual stimuli. This process repeated for all 20 exposures.

Read-Do Probes. The experimenter presented the read-do probe to the participant as an assignment on Google Classroom. Immediately after the Reading Experience, the experimenter provided the vocal instruction, "Read the steps on slide 2 and build the picture on slide 3." After the participant completed the probe, the participant "Turned In" the assignment to ensure that the participant could not revise their responses. The experimenter scored the participant's responses according to a predetermined rubric and calculated the total number of correct responses out of ten. The experimenter did not provide any feedback for participant responses.

Establishment of Inc. BiN for Unfamiliar Stimuli

The experimenter established Inc. BiN for unfamiliar stimuli in the manner described above. When the participant emitted a correct response, the experimenter recorded a plus (+) and when the participant emitted an incorrect response, the experimenter recorded a minus (-). At the end of each session, the experimenter calculated the total number of correct responses across each response topography.

Post-Inc. BiN Probes

When the participant demonstrated Inc. BiN stimulus control for unfamiliar stimuli, the experimenter conducted postintervention read-do probes, passage comprehension probes, and

WJIV® assessments to determine the effect of the establishment of Inc. BiN on reading comprehension performance. The aforementioned probes were conducted in the same manner as pre-Inc. BiN conditions.

Interobserver/Interscorer Agreement

The experimenter collected interobserver agreement (IOA) through trial-by-trial agreement. Due to the virtual method of data collection, all sessions were screen recorded, which allowed auditory recording of participants' vocal responses and visual observation of participants' listener responses when applicable. After a second, independent observer assessed IOA for a particular session, the experimenter permanently deleted the recording. The second, independent observer also received a copy of the passage comprehension rubric for scoring purposes and copies of the necessary data sheets.

Across reading comprehension measures, IOA was conducted for 37.50% of *WJIV*® Passage Comprehension assessments with a mean agreement of 98.92% (range 96.77-100%). IOA was collected for 50% of *WJIV*® Reading Recall assessments, with a mean agreement of 95.92% and a range of 95.45-100%. Across IOA conducted for 50% of *WJIV*® Reading Vocabulary assessments, the mean agreement was 100. For experimenter-derived passage comprehension probes, IOA was collected for 40.74% of probes, with a mean agreement of 99.09% and a range of 90-100%. For Inc. BiN intervention sessions, IOA was conducted for 32.74% of sessions with a mean agreement of 99.19% and range of 90-100%.

The experimenter collected interscorer agreement (ISA) for Read-Do probes by presenting the independent observer with the copy of the participants' responses and the scoring rubric. ISA was conducted for 41.67% of sessions with 98% mean agreement and range of 90-100%

Treatment Fidelity

Treatment fidelity was measured by conducting Teacher Rate/Performance Accuracy (TPRA) observations (Ingham & Greer, 1992). TPRA observations measure the following: (1) whether the experimenter is presenting the correct, unambiguous vocal instruction to the participant that does not prompt the correct response, (2) whether the participant's response was correct or incorrect, and (3) ensures that the experimenter does not provide any corrections or reinforcement when it is not needed. The experimenter conducted treatment fidelity for 32.74% of intervention sessions, with a mean fidelity of 100%.

Results

WJIV® Subtests

Mean Performance and Differences across Subtests

Figure 3 shows the *WJIV*® standard scores across all participants for each *WJIV*® subtest prior to and following the establishment of Inc. BiN stimulus control for unfamiliar stimuli. Figure 4 displays the mean *WJIV*® standard score, taken across all subtests, demonstrated by participants before and after achieving BiN stimulus control for unfamiliar stimuli. Table 10 displays the summary of *WJIV*® results for all participants across each subtest pre- and postintervention. Results in this table include: standard scores and mean standard scores, percentile rank, number of correct responses, and grade-level equivalent performance. Overall, the mean standard score across all subtests was 106, which increased to 115 following the establishment of Inc. BiN stimulus control, for a mean difference of +8.

Prior to the establishment of Inc. BiN stimulus control for unfamiliar stimuli, the mean standard score for Test 4: Passage Comprehension across participants was 94, which increased to a mean of 105 for a mean difference of +11. Across Test 12: Reading Recall standard scores, participants demonstrated a mean standard score of 115 with a mean difference of +7 following the establishment of Inc. BiN stimulus control. For Test 17: Reading Vocabulary, the mean standard score increased from 110 to 117, for a mean difference of +7.

Test 4: Passage Comprehension

Across all participants, an ascending trend was observed in both the Passage Comprehension subtest standard scores and percentile rank after participants demonstrated Inc. BiN stimulus control for unfamiliar stimuli (Figure 3). With the exception of Participant 2, who increased his standard score by 6, all participants increased their standard score by at least 10. Participant 5 demonstrated the greatest increase following the intervention, with an increase in standard score of 14, followed by Participant 3, who increased his standard score by 13. When converted to percentile rank, these participants also demonstrated the greatest gains with increases of 36 and 34, respectively. Prior to the establishment of Inc. BiN for unfamiliar stimuli, all participants scored below the 50th percentile, with Participant 1 scoring the highest, in the 47th percentile. Following the establishment of Inc. BiN for unfamiliar stimuli, all participants scored at least at or above the 50th percentile (Table 10).

Test 12: Reading Recall

For Reading Recall subtests, an ascending trend was observed across standard scores and corresponding percentile ranks following the establishment of Inc. BiN stimulus control for unfamiliar stimuli for all participants (Figure 3). Participants 1, 2, and 6 demonstrated smaller gains of 3, 3, and 4, respectively, when compared to Participants 3, 4, and 5, who demonstrated gains of 12, 12, and 7, respectively (Table 10). These increases in standard score were also observed to corresponding percentile ranks, with Participants 1, 2, and 5 demonstrating increases of 3, 3, and 2, respectively, and Participants 3, 4, and 6 demonstrating increases of 16, 27, and 10, respectively.

Test 17: Reading Vocabulary

Similar to the other two subtests, an ascending trend was also observed across both Reading Vocabulary standard score and percentile rank (Figure 3). Participant 3 demonstrated the fewest gains after intervention, with an increase in standard score of 1, while the other participants demonstrated an increase of standard score of 5 to 11 (Table 10). Similar to Reading Recall performance, participants who scored in lower percentile ranks (i.e., Participants 2 and 4) demonstrated the greatest increases in percentile rank.

Table 10

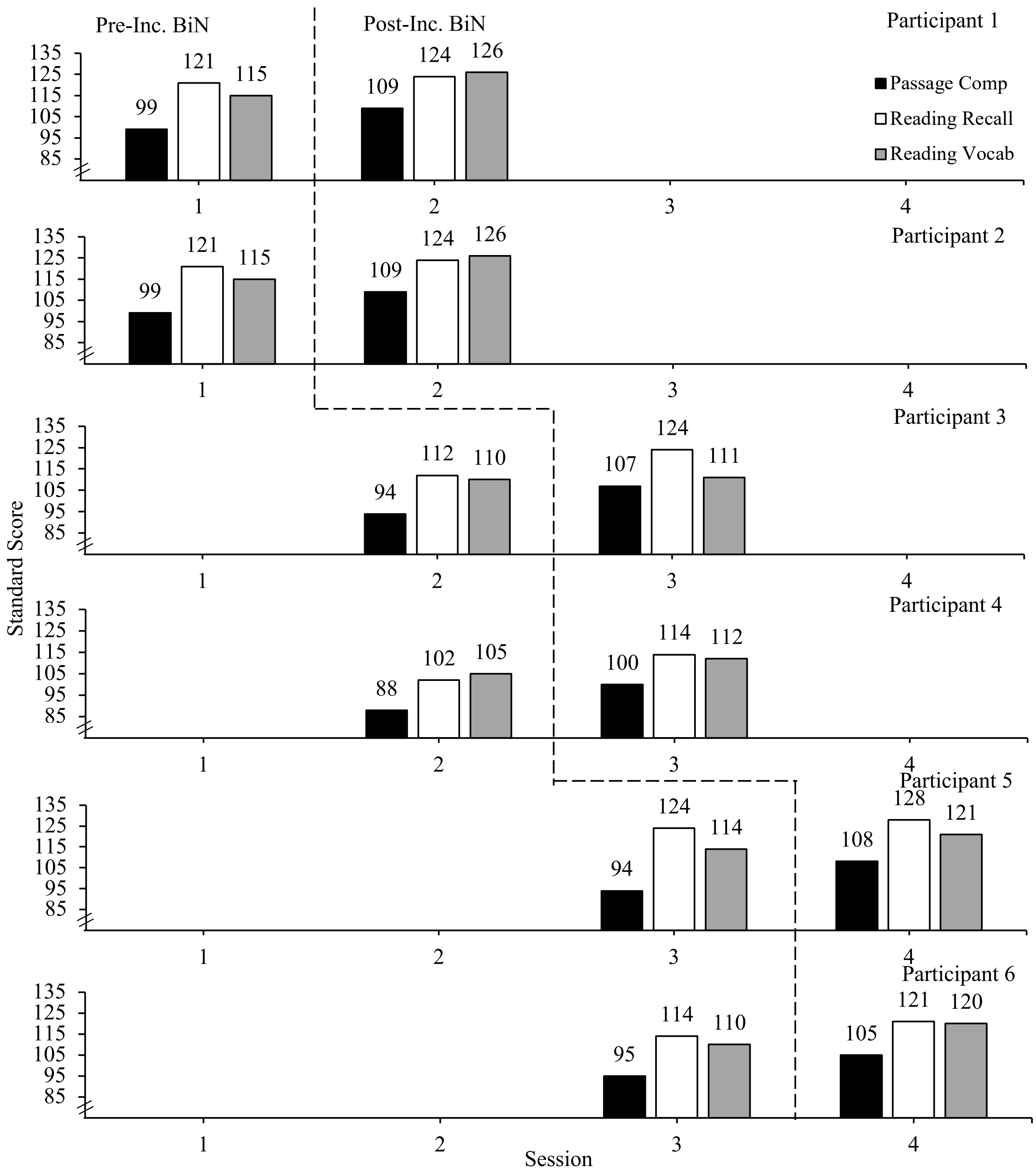
Summary of WJIV® Results across Participants in Experiment 2

		Standard Score				Percentile Rank			Number Correct			Grade Level Equivalent		
		Comp	Recall	Vocab	*M*	Comp	Recall	Vocab	Comp	Recall	Vocab	Comp	Recall	Vocab
P1	Pre	99	121	115	112	47	92	84	18	29	13	1.6	3	2.4
	Post	109	124	126	120	73	95	96	24	52	19	2.5	4.9	4
	Change	10	3	11	8	26	3	12	6	23	6	0.9	1.9	1.6
P2	Pre	95	119	105	106	37	90	63	17	29	10	1.6	3.5	1.8
	Post	101	122	110	111	53	93	75	22	43	13	2.1	4.4	2.4
	Change	6	3	5	5	16	3	12	5	14	3	0.5	0.9	0.6
P3	Pre	94	112	110	105	34	79	75	18	25	13	1.6	2.8	2.4
	Post	107	124	111	114	68	95	77	25	56	14	2.7	4.4	2.6
	Change	13	12	1	9	34	16	2	7	31	1	1.1	1.6	0.2
P4	Pre	88	102	105	98	21	55	63	16	19	12	1.4	2	2.2
	Post	100	114	112	109	50	82	79	23	28	15	2.3	2.8	2.9
	Change	12	12	7	10	29	27	16	7	9	3	0.9	0.8	0.7
P5	Pre	94	124	114	111	34	95	82	20	36	13	1.9	3.5	2.4
	Post	108	128	121	119	70	97	92	24	60	17	2.5	5.9	3.4
	Change	14	4	7	8	36	2	10	4	24	4	0.6	2.4	1
P6	Pre	95	114	110	106	37	82	75	14	20	10	1.2	2.1	1.8
	Post	105	121	120	115	63	92	91	19	35	14	1.8	3.7	2.6
	Change	10	7	10	9	26	10	16	5	15	4	0.6	1.6	0.8
M	Pre	94	115	110	106	-	-	-	-	-	-	-	-	-
	Post	105	122	117	115	-	-	-	-	-	-	-	-	-
	Change	11	7	7	8	-	-	-	-	-	-	-	-	-

Note: Pre- and Post- represents performance before and after the establishment of Inc. BiN stimulus control.

Figure 3

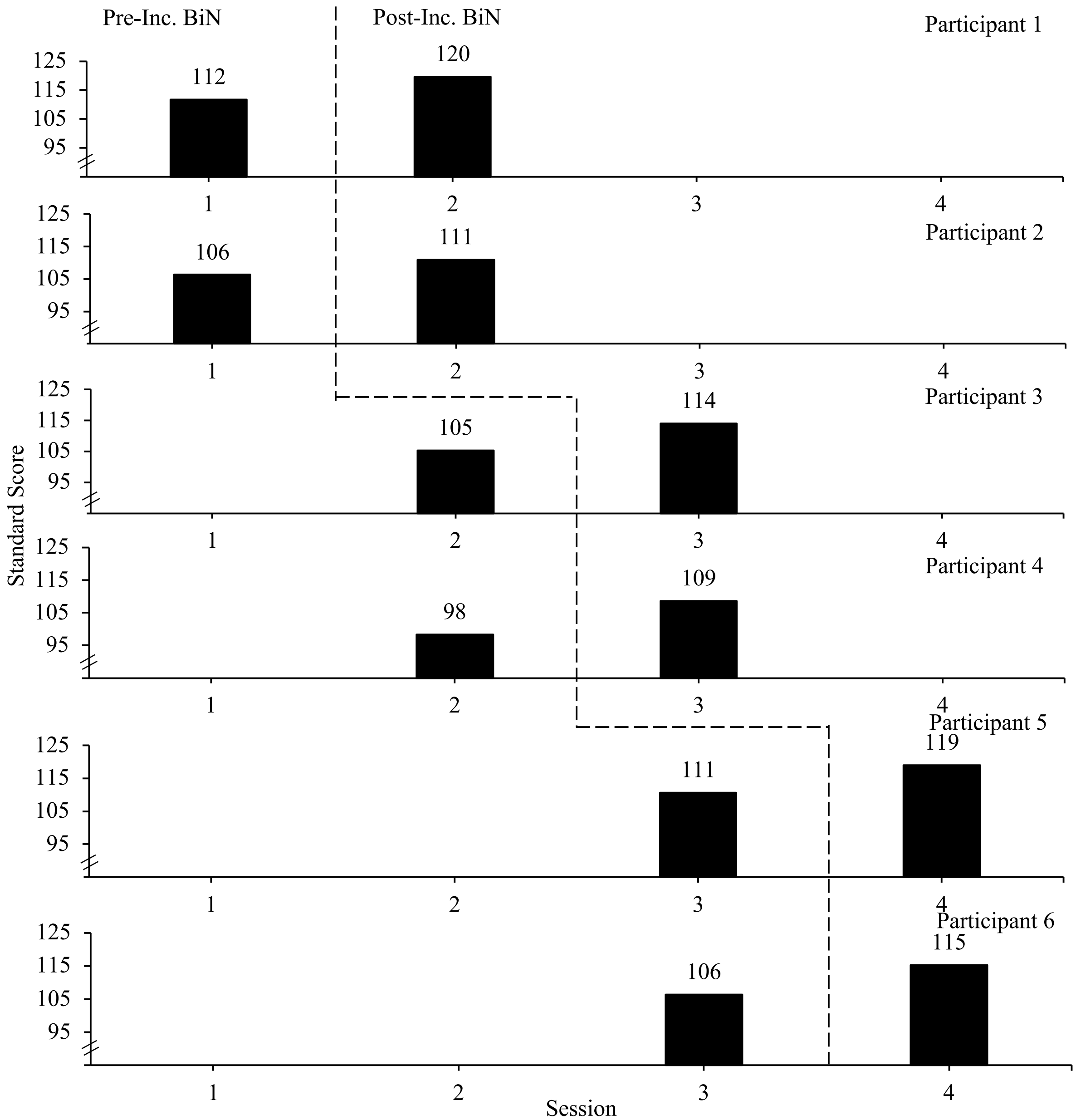
WJIV® Standard Score across Subtests for Participants in Experiment 2



Note: This figure shows participants' *WJIV®* standard score prior to and following the establishment of Inc. BiN stimulus control for unfamiliar stimuli across the following subtests: Passage Comprehension (Test 4), Reading Recall (Test 12), and Reading Vocabulary (Test 17).

Figure 4

Mean WJIV® Standard Score across Participants in Experiment 2



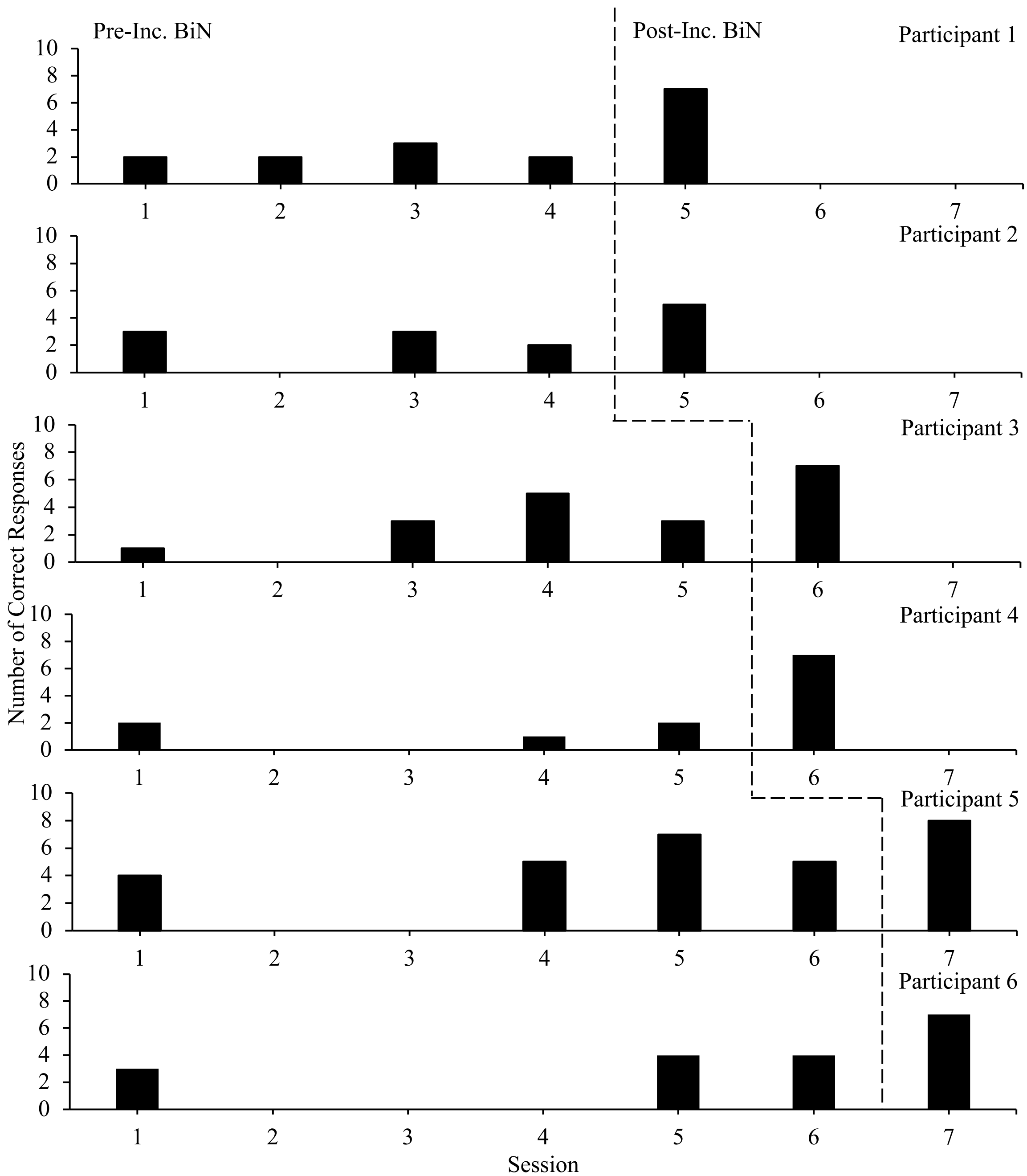
Note: This figure shows the mean *WJIV®* standard score of each participant, taken across all subtests, prior to and following the establishment of Inc. BiN stimulus control for unfamiliar stimuli.

Experimenter-Derived Passage Comprehension

Figure 5 shows the number of correct responses emitted during experimenter-derived passage comprehension probes across dyads prior to and following the establishment of Inc. BiN stimulus control for unfamiliar stimuli. Pre-Inc. BiN probes demonstrated low (i.e., less than 5) correct responses following steady state responding. Following the establishment of Inc. BiN stimulus control for unfamiliar stimuli, an ascending trend was observed across all participants in the number of correct responses emitted during passage comprehension probes. The largest increases in correct responses were observed for Participants 1, 3, and 4, whose correct responses increased by 5, 4, and 5, respectively, whereas marginal increases of 2, 3, and 3 correct responses were observed for Participants 2, 5, and 6, respectively. On average, participants' number of correct responses increased from their last pre-Inc. BiN probe by 3.83.

Figure 5

Number of Correct Responses for Experimenter-Derived Passage Comprehension Probes



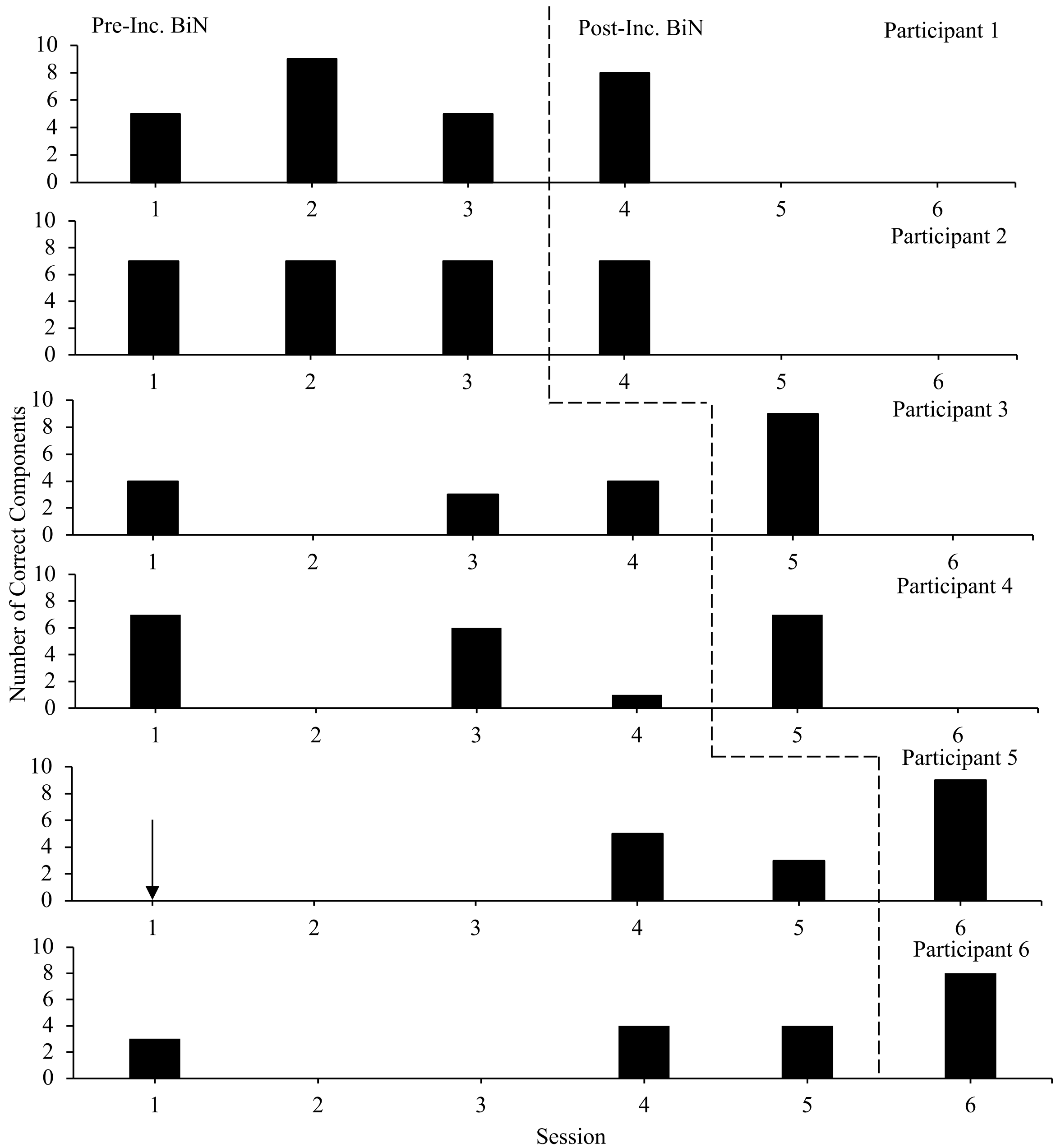
Note: This figure displays the number of correct responses to experimenter-derived passage comprehension probes prior to and following the establishment of Inc. BiN stimulus control. Each probe consisted of a novel fiction and nonfiction text at the participants' reading level.

Read-Do Correspondence for Unfamiliar Stimuli

Figure 6 shows the number of correct components of read-do probes emitted by participants prior to and following the establishment of Inc. BiN stimulus control for unfamiliar stimuli. Overall, results were variable in both pre-Inc. BiN and post-Inc. BiN conditions, with the exception of Participants 3 and 6. Participants 1, 4, and 5 demonstrated variable pre-Inc. BiN correct components across three baseline probes with a descending or no trend observed by the third pre-Inc. BiN probe, whereas Participants 2, 3, and 6 demonstrated less variable, stable responding in baseline conditions prior to the establishment of Inc. BiN stimulus control for unfamiliar stimuli. Regardless of the variability of pre-Inc. BiN probes, an ascending trend in correct components was observed following the establishment of Inc. BiN stimulus control for unfamiliar stimuli across all participants with the exception of Participant 2, whose correct components emitted post-Inc. BiN remained stable (i.e., 0 increases following intervention). More specifically, a marginal increase (i.e., 3 correct components) was observed for Participant 1, whereas larger increases were observed for Participants 3, 4, 5, and 6 (i.e., an increase of 5, 6, 6, and 4 correct components, respectively). These increases were observed between the third and final pre-Inc. BiN probe and post-Inc. BiN probe. The mean increase between correct components emitted in the third pre-Inc. BiN probe and correct components emitted post-Inc. BiN was 4 correct components across all participants.

Figure 6

Number of Correct Components across Read-Do Probes



Note: This figure displays the number of correct components emitted across read-do probes for unfamiliar stimuli before and after the establishment of Inc. BiN stimulus control for unfamiliar stimuli. Each probe represents a novel stimuli set that participants were exposed to via a simulated "Reading Experience" immediately before the probe.

Establishment of Inc. BiN for Unfamiliar Stimuli

Dyad 1

Figure 7 displays the intervention data to establish Inc. BiN stimulus control for unfamiliar stimuli for dyad 1 (i.e., Participants 1 and 2). Dyad 1 began intervention undergoing a repeated probe intervention (Lo, 2016; Kleinert, 2018), in which the experimenter presented a probe for a single set of target stimuli multiple times following a single NE until 90% accuracy across both response topographies.

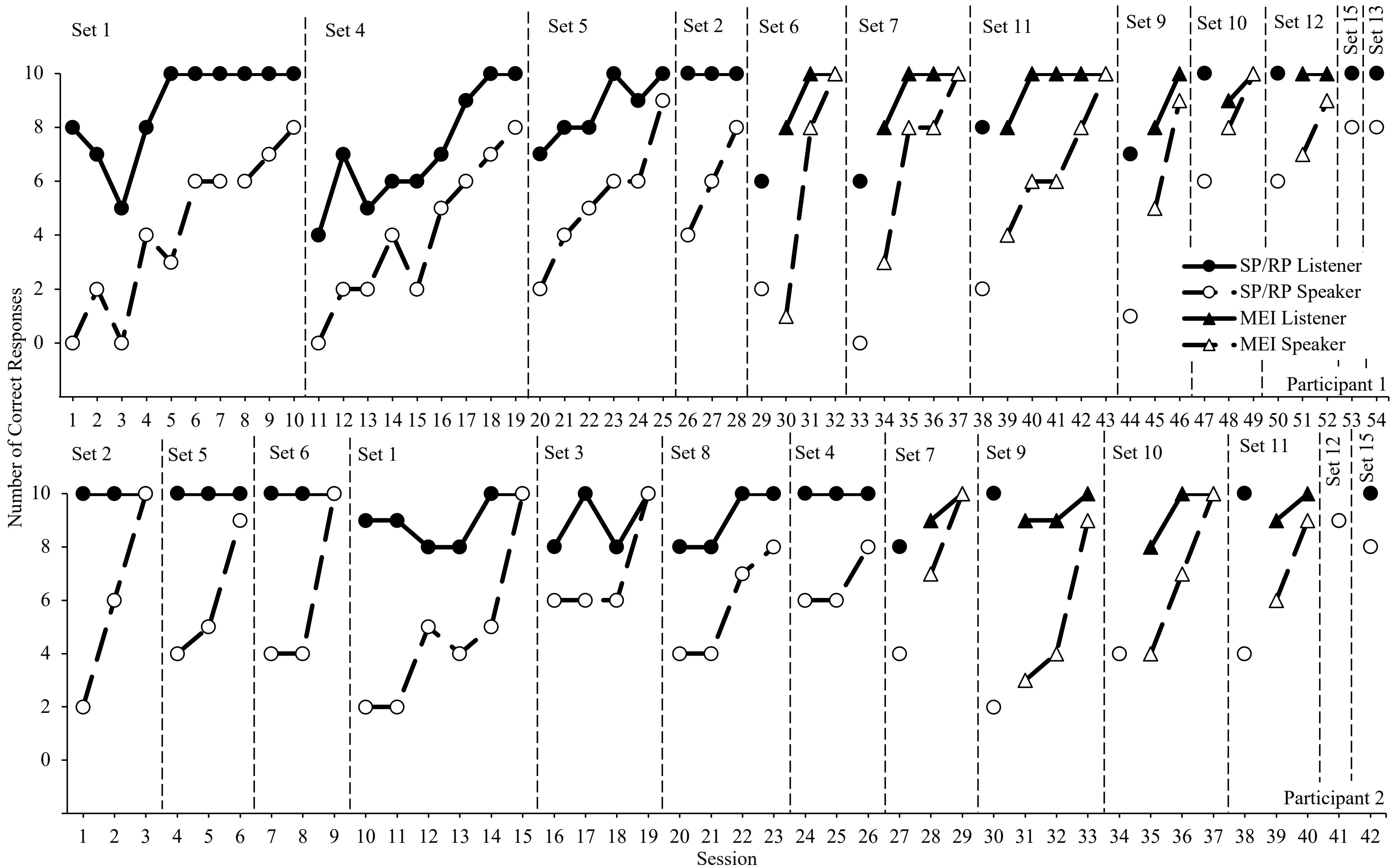
However, due to internet connectivity problems causing time lags in paired auditory-visual stimuli presentations, the repeated probe intervention was determined to be ineffective (i.e., paired auditory-visual stimuli presentations were not functioning to condition observing responses to see and say the stimulus without direct teaching) and a verbally mediated decision was made to change to the MEI intervention. In other words, the delay between the presentation of the auditory and visual stimulus due to internet connectivity caused the respondent conditioning mechanism of the repeated probe intervention to become ineffective at establishing Inc. BiN stimulus control for unfamiliar stimuli. Although Participant 1 demonstrated increased strength in Inc. BiN stimulus control with each subsequent, novel set (i.e., descending trend in number of sessions to achieve mastery), Participant 2 demonstrated no trend in the number of sessions to achieve mastery across 7 novel sets. Therefore, both participants in the dyad underwent MEI to establish Inc. BiN stimulus control after 29 sessions and 27 sessions for Participants 1 and 2, respectively.

Participant 1 (Figure 7, top panel) achieved mastery criterion for 4 sets of the repeated probe intervention across 28 sessions for a total of 560 probe trials. With each subsequent stimuli set, Participant 1 required fewer sessions to achieve criterion, requiring 10 sessions for Set 1, 9 sessions for Set 4, 6 sessions for Set 5, and 3 sessions for Set 2. Participant 2 (Figure 7, bottom panel) mastered 7 sets across 26 sessions for a total of 520 probe trials. However, unlike Participant 1, he did not demonstrate any descending trends regarding the number of probe sessions to achieve mastery, requiring 3, 3, 3, 6, 4, and 3 probe sessions to achieve mastery.

Following the implementation of MEI across point-to and intraverbal tact responses, Participant 1 mastered 6 sets across 19 sessions of MEI with a learn units-to-criterion (LUC) rate of 63.33 before acquiring Inc. BiN stimulus control for unfamiliar stimuli at 100% accurate listener responses and 80% accurate speaker responses across one single Inc. BiN probe for Set 15 and 100% and 80% accurate listener and speaker responses, respectively, across one single BiN probe for Set 13. Including the two final Inc. BiN probes (i.e., Set 15 and 13), Participant 1 received 8 total single Inc. BiN probes (i.e., 8 different stimuli sets) for a total of 160 probe trials in the MEI phase of intervention. Participant 2 required fewer target stimuli sets and fewer sessions of MEI to acquire BiN stimulus control for unfamiliar stimuli. Participant 2 mastered 4 sets across 10 sessions of MEI with a LUC of 50. He demonstrated Inc. BiN stimulus control at 90% accuracy for both listener and speaker responses across a single probe for Set 12, followed by 100% correct listener responses and 80% correct speaker responses across a single probe for Set 15. In total, Participant 2 received 4 single Inc. BiN probes (i.e., 4 different stimuli sets) for a total of 80 probe trials during the MEI phase of intervention.

Figure 7

Establishment of Inc. BiN Stimulus Control for Unfamiliar Stimuli for Dyad 1



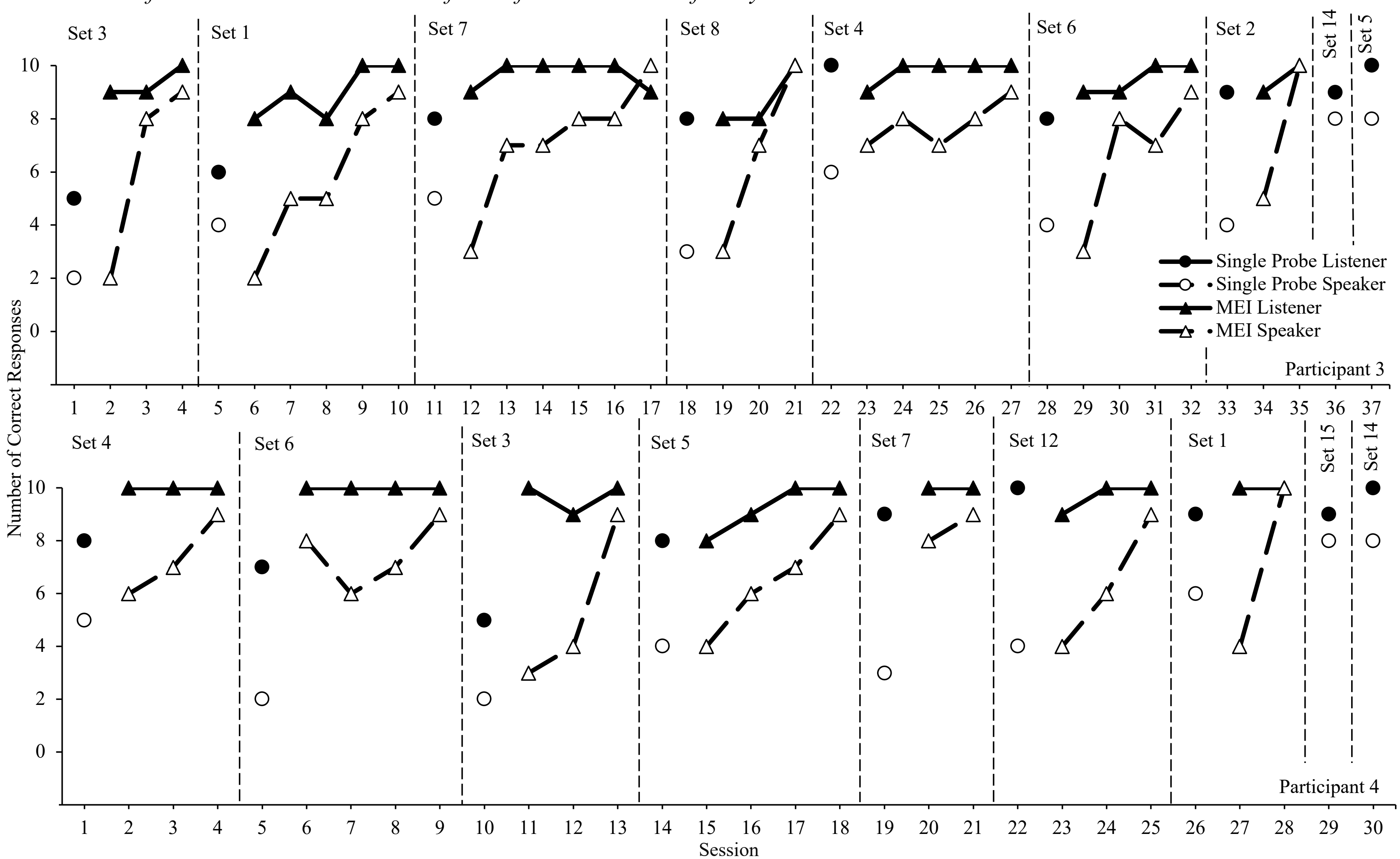
Note: SP/RP represent single and repeated probes, in which participants received no feedback for correct or incorrect responses.

Dyad 2

Figure 8 displays the intervention data for Dyad 2, which consisted of Participants 3 and 4, who only received the MEI intervention to establish Inc. BiN stimulus control for unfamiliar stimuli. Both Participant 3 (top panel) and 4 (bottom panel) mastered 7 target stimuli sets through MEI and received 9 total single Inc. BiN probes (180 probe trials) before demonstrating Inc. BiN stimulus control for unfamiliar stimuli. Participant 3 mastered 7 sets of MEI across 28 sessions for a LUC rate of 80, while Participant 4 mastered 7 sets of MEI across 21 sessions for a LUC rate of 60. Participant 3 acquired Inc. BiN stimulus control after emitting 90% correct listener responses and 80% speaker responses across a single Inc. BiN probe for Set 14, followed by a consecutive single Inc. BiN probe for Set 5 with 100% correct listener responses and 80% correct speaker responses. Participant 4 demonstrated Inc. BiN stimulus control after emitting the same correct responding as Participant 3.

Figure 8

Establishment of Inc. BiN Stimulus Control for Unfamiliar Stimuli for Dyad 2



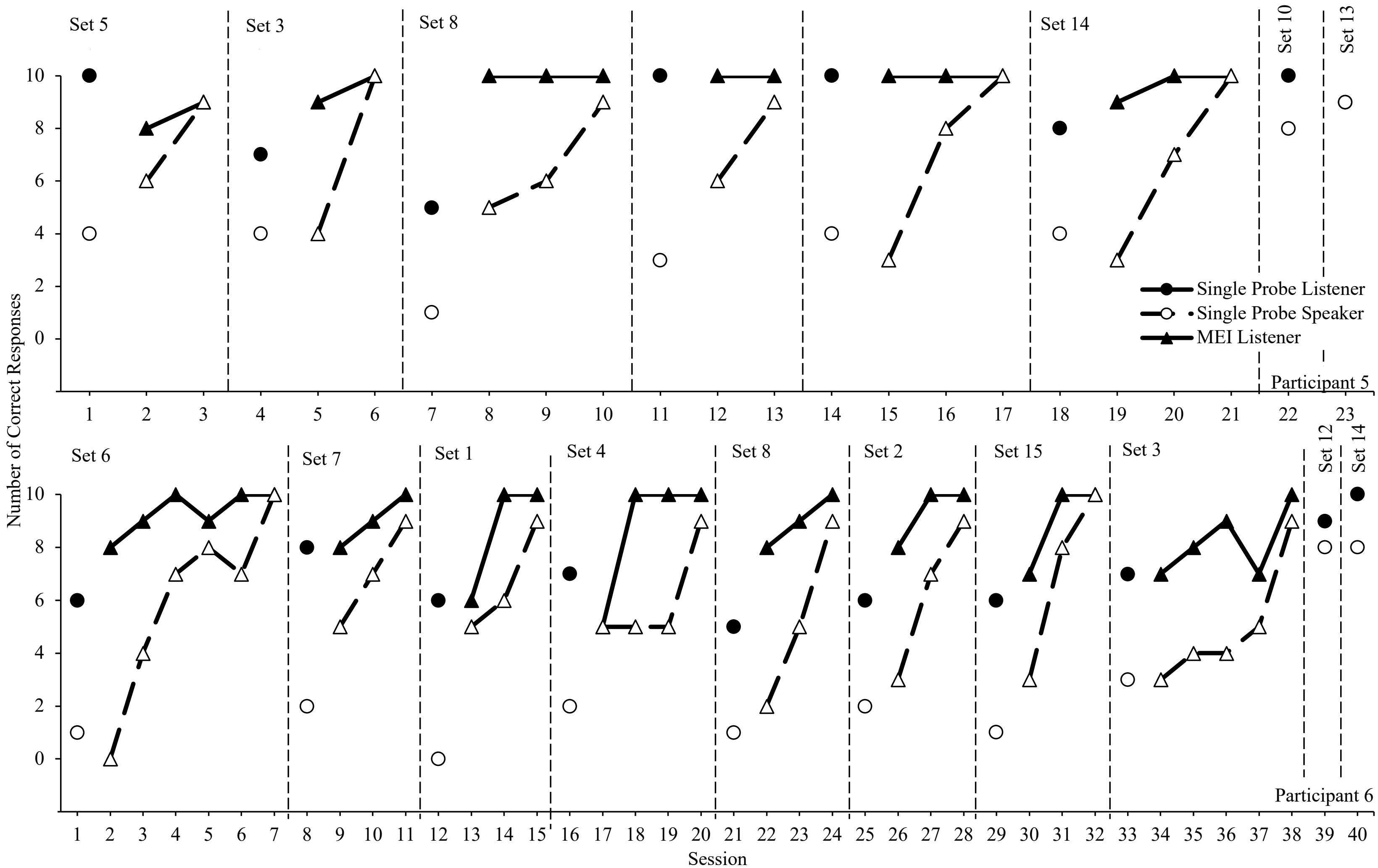
Note: The first session for each set consisted of a single probe to assess strength of Inc. BiN stimulus control and need for MEI.

Dyad 3

Figure 9 displays the intervention data for Dyad 3, which included Participants 5 (top panel) and 6 (bottom panel). Participant 5 acquired Inc. BiN stimulus control for unfamiliar stimuli after receiving 8 single Inc. BiN probes (160 probe trials). He mastered 6 target stimuli sets of MEI across 15 MEI sessions for a LUC rate of 50. He required the fewest sessions of MEI before demonstrating Inc. BiN stimulus control at 100% correct listener responses and 80% correct speaker responses across a single Inc. BiN probe for Set 10, followed by a consecutive, single Inc. BiN probe for Set 13 with 90% accuracy across both listener and speaker responses. Participant 6 received the most single Inc. BiN probes (10 single Inc. BiN probes and 200 probe trials) and required the greatest number of MEI sessions (30 sessions) before demonstrating Inc. BiN stimulus control. Across 8 mastered sets through MEI, Participant 6's LUC was also the highest across all participants at a rate of 75. She acquired Inc. BiN stimulus control for unfamiliar stimuli after emitting 90% correct listener responses and 80% correct speaker responses across a single Inc. BiN probe for Set 12 and 100% correct listener responses and 80% speaker responses across a consecutive single Inc. BiN probe for Set 14.

Figure 9

Establishment of Inc. BiN Stimulus Control for Unfamiliar Stimuli for Dyad 3



Note: The first session for each set consisted of a single probe to assess strength of Inc. BiN stimulus control and need for MEI

Discussion

Overall, the findings demonstrate the effects of the establishment of Inc. BiN stimulus control for unfamiliar stimuli on multiple forms of reading comprehension for first grade students. Multiple measures of reading comprehension in the present study consisted of (1) three standardized measures of reading comprehension according to *WJIV*® subtests, (2) functional, novel vocabulary acquisition in the form of read-do correspondence probes, and (3) explicit questions (i.e., "Wh" questions) in experimenter-derived passage comprehension probes. Across all measures, reading comprehension improved as a function of the establishment of Inc. BiN stimulus control for unfamiliar stimuli.

In terms of arbitrarily applicable relational responding, reading comprehension measures assessed the formation of multiple forms of relations when responding to reading (i.e., reading comprehension). Experimenter-derived passage comprehension probes assessed the formation of mutually entailed relations between textual responses and the specific "Wh" question presented. Read-do probes assessed the participants' mutually entailed and combinatorially entailed reading comprehension responses for novel word-object relations. The mutually entailed relation (A-B) consists of the relation between the printed word (A) and unfamiliar picture (B), while there are multiple combinatorially entailed relations between the A-B relation and other operants – relational responding in repertoire, such as orientation and color, word-object relations not directly presented (i.e., forming and responding to word-object relations by exclusion), and in reference to other newly formed word-object relations presented in the "Reading Experience." Across WJIV® subtests, Passage Comprehension and Reading Vocabulary subtests required the formation of combinatorially entailed relations (i.e., among the textual response itself, known vocabulary/operants in repertoire, and in relation to the sentence/word presented), while the

Reading Recall subtest required the formation of mutually entailed relations only (i.e., between textually responding and repeating the content of the text with point-to-point correspondence).

Thus, the question becomes – how does the formation of Inc. BiN stimulus control, one of the earliest and foundational relational frames (Barnes-Holmes et al., 2001), transform the reader-as-own listener repertoire in terms of mutually entailed and combinatorially entailed relations?

The most significant increases in reading comprehension performance were found across *WJIV*® Passage Comprehension, followed by *WJIV*® Reading Recall performance, *WJIV*® Reading Vocabulary performance, and experimenter-derived passage comprehension probes, with marginal and significant increases demonstrated across both of the latter probes for all participants. Thus, it seems possible that the acquisition of Inc. BiN stimulus control for unfamiliar stimuli (i.e., a more complex level of Inc. BiN stimulus control) sets the occasion for the participant to build their reader-as-own listener repertoire in terms of forming novel relations among the text and previously learned experiences.

Despite assessing a simpler mutually entailed relation, increases in *WJIV*® Reading Recall were more marginal when compared to the other measures. However, preexperimental probes indicated that all participants had some degree of Inc. BiN. In particular, participants demonstrated higher degrees of UniN stimulus control for both familiar and unfamiliar stimuli. It is possible that participants similarly had some degrees of forming the mutually entailed relation of recall and thus, strengthening more complex levels of Inc. BiN stimulus control demonstrated a more marginal effect.

Although Participants 1, 3, and 4 demonstrated educationally significant increases in experimenter-derived passage comprehension probes, marginal increases were demonstrated by

Participants 2, 5, and 6 (Figure 5). This form of reader-as-own listener responding may also appear to be simpler than measures in which participants demonstrated greater increases (i.e., *WJIV*® Passage Comprehension and Reading Recall). However, the experimenter-derived passage comprehension probe required participants to respond without the presence of the text, which consisted of multiple sentences that varied in content and structure, whereas *WJIV*® Passage Comprehension and Reading Vocabulary consisted of texts with fewer words or sentences. Furthermore, participants had access to the text for both of these measures while responding. Therefore, it seems plausible that three participants demonstrated only marginal increases in experimenter-derived passage comprehension probes because a more complex level of Inc. BiN is required for forming specific, mutually entailed responses without the presence of the text.

There were inconsistent findings for the number of correct components emitted in unfamiliar read-do probes across participants, in which only Participants 3 and 6 demonstrated significant increases following the acquisition of Inc. BiN stimulus control for unfamiliar stimuli (Figure 6). Due to the combinatorially entailed relational responding required to demonstrate read-do correspondence for the target unfamiliar stimuli, it is possible that the acquisition of more complex forms of Inc. BiN and/or more complex derived relational responding is required to not only form the relation between printed word and object, but also to relate those operants to other newly formed word-object relations, to word-object relations not directly presented (i.e., exclusion), and to actions in repertoire (i.e., left/right/top/bottom/middle orientation and color).

The subsequent chapter will provide further analysis of the major findings of the present study in addition to contributions to the field of behavior analysis and education, limitations, implications for educational practice and suggestions for future research.

Chapter 4: General Discussion

Summary of Findings

In two experiments, I studied the relationship between increasing levels of complexity for Inc. BiN stimulus control and various measures of reading comprehension for first graders. Findings across both experiments add to the existing body of research in behavior analysis by demonstrating how increasing degrees of Inc. BiN stimulus control joins previously learned relations to develop reading comprehension. Helou-Care (2009) joined Inc. BiN stimulus control to print stimuli and Laurent-Prophete (2017) trained mutually and combinatorially entailed reading comprehension relations through the utilization of *Corrective Reading* (Engelman et al., 1999). Given that more recent research has demonstrated the relationship between Inc. BiN stimulus control and relational responding and the distinction of Inc. stimulus control as a continuum with varying levels of complexities (Morgan et al., 2020; Friedman, 2020), the current study sought to provide a more comprehensive account of the relationship between increased complexity of Inc. BiN stimulus control and varying forms of reading comprehension.

In Experiment 1, I determined whether differences in levels of complexity for Inc. BiN stimulus control (i.e., degrees of Inc. BiN across familiar and unfamiliar stimuli) were a statistically significant factor in relating to and comparing differences on reading comprehension performance. Degrees of Inc. BiN for familiar stimuli and degrees of UniN for unfamiliar stimuli demonstrated the most statistically significant and greatest positive correlations with reading comprehension measures. One-way ANOVA results demonstrated that across varying categories of Inc. BiN stimulus control, there were significant differences in three out of the six reading comprehension measures, whereas there were significant differences in five out of the six reading comprehension measures across categories of Inc. BiN stimulus control for unfamiliar stimuli. Overall, these findings suggest that although degree of UniN for familiar stimuli and degree of Inc. BiN for unfamiliar stimuli both relate to and predict reading comprehension performance, increasing levels of complexity for Inc. BiN stimulus control (i.e., from familiar to unfamiliar) demonstrate the greatest differences.

Experiment 2 built on these findings by increasing the level of complexity for Inc. BiN by establishing Inc. BiN stimulus control for unfamiliar stimuli, which no participant demonstrated stimulus control for in Experiment 1. The purpose of this study was to determine whether multiple measures of reading comprehension increased as a function of increased degree of Inc. BiN for unfamiliar stimuli in a single-case experimental design for six first graders. I measured reading comprehension using the same *WJIV*® subtests from Experiment 1 in addition to two experimenter-derived assessments: passage comprehension and read-do correspondence for unfamiliar stimuli. Following the establishment of Inc. BiN stimulus control for unfamiliar stimuli, results demonstrated increases across almost all reading comprehension measures, with the exception of read-do probes. The greatest increases were found in *WJIV*® Passage Comprehension performance, followed by *WJIV*® Reading Vocabulary, *WJIV*® Reading Recall, and experimenter-derived passage comprehension probes.

Major Findings

See-Say Correspondence, Self-Listening, and Reading

As demonstrated in previous research, Inc. BiN stimulus control emerges as a function of a history of reinforcement for correspondence between seeing visual stimuli and saying auditory stimuli (Lo, 2016; Kleinert et al., submitted). That is, prior experience with hearing and seeing novel stimuli sets the occasion for the demonstration of novel word-object relations. Alsharif (2020) demonstrated that listening to one's own voice, or self-listening, was critical in the development of governing one's own behavior within the skin and thus, in the development of the reader-as-own listener repertoire. In other words, one develops the correspondence between hearing oneself and doing the corresponding action, which Alsharif (2020) demonstrated through read-do probes. Given that all participants in Experiment 2 demonstrated read-do correspondence for familiar stimuli in preexperimental probes, it is possible that the establishment of Inc. BiN stimulus control for unfamiliar stimuli extended stimulus control for self-listening. Accordingly, participants listened to their own textual responses and responded to their textual responses, not in the form of performing an action (i.e., read-do), but rather in the form of combinatorially entailed relations between novel and previously learned experiences.

Increased Levels of Complexity for Inc. BiN and Reading Comprehension

Experiment 1 first demonstrated that greater reading comprehension performance was related to more complex levels of Inc BiN in the form of higher degrees of Inc. BiN stimulus control (i.e., the number of correct untaught listener and speaker responses) and distinguishing between familiar and unfamiliar stimuli. However, data were inconclusive regarding the relationship between the most complex form of Inc. BiN stimulus control assessed – degrees of Inc. BiN for unfamiliar stimuli – because no participants demonstrated responding at this level of complexity. Experiment 2 addressed these gaps in the findings of Experiment 1 by establishing this level of Inc. BiN stimulus control to determine its effects on reading comprehension performance. By establishing Inc. BiN stimulus control for unfamiliar stimuli, the results demonstrated increases in *WJIV*® Passage Comprehension, which was not significantly predicted by degrees of UniN and BiN for familiar and unfamiliar stimuli in Experiment 1. This suggests that as stimulus control extends to more complex levels of Inc. BiN, more complex mutually entailed and combinatorially entailed relations form from novel experiences in reading.

Developmental Trajectory of Reader-as-Own Listener Behavior

Increases in reading comprehension performance in Experiment 2 suggest the establishment of various mutually entailed and combinatorially entailed relations in the reader-as-own listener repertoire. The two mutually entailed assessments consisted of *WJIV*® Reading Recall and experimenter-derived passage comprehension probes. When compared to gains in the other reading comprehension measures, the average gains across participants for these two measures were relatively smaller (Figure 3; Figure 5). Given that participants all demonstrated UniN stimulus control for familiar stimuli and all but one participant demonstrated UniN stimulus control for unfamiliar stimuli in preexperimental probes, participants likely had some degree of stimulus control for mutually entailed responding in the form of textual responses and vocal responses with point-to-point correspondence with the text. This is also reflected in participants' greater standard scores (M = 115) when compared to the other two subtests.

The greatest increases were observed in *WJIV*® Passage Comprehension, in both standard score and percentile rank. This subtest assessed combinatorially entailed reading comprehension by requiring participants to form relations between textual responses, previously learned experiences, and the context of the sentence(s). Given that greater gains were observed for this measure when compared to *WJIV*® Reading Recall – a simpler, mutually entailed relation – this implies that more complex, combinatorially entailed reading comprehension may emerge as more complex levels of Inc. BiN stimulus control are acquired. In other words, the correspondence for seeing and saying between word-object relations as established in Inc. BiN stimulus control set the occasion for participants to emit relations between not just textual responses and doing, but also among textual responses, previously learned relations, and newly formed relations.

This is also supported by findings that demonstrated fewer gains in *WJIV*® Reading Vocabulary performance and read-do probes for unfamiliar stimuli. Although *WJIV*® Reading Vocabulary also required combinatorially entailed responding, it is possible that this measure required more complex relating to previously learned experiences, especially considering that participants were required to respond to one word; whereas in *WJIV*® Passage Comprehension, participants responded to a sentence or multiple sentences. The need for more complex Inc. BiN stimulus control to form relations between novel stimuli presented in text and previously learned relations is also reflected in participants' relatively variable, marginal increases in read-do probes for unfamiliar stimuli. This measure consisted of multiple combinatorially entailed relations, which involved textual responses, correspondence between the picture and printed word, relational responding in repertoire (i.e., orientation and color), relating to a novel picture-word relation (i.e., exclusion), and relational responding among picture-word stimuli. Overall, these results suggest that as relations become more complex, greater levels of complexity for Inc. BiN may be necessary.

Limitations

Experiment 1

Catts and Kamhi (2017a) identified reading comprehension as consisting of multiple abilities, including decoding (i.e., textually responding), content knowledge, and language comprehension. Given that this study consisted of first graders with varying degrees of textually responding accuracy and fluency, controlling for decoding ability would have demonstrated more accurately how responding to reading comprehension tasks is related to previously learned experiences and verbal ability.

Furthermore, degree of Inc. BiN stimulus control only consisted of a single probe – a single probe for familiar stimuli and a single probe for unfamiliar stimuli. Previous literature suggests that each exposure to novel stimuli can strengthen Inc. BiN stimulus control and accordingly, students may emit varying degrees of Inc. BiN stimulus control across successive exposures to novel stimuli (i.e., "brief exposure;" Friedman, 2020). Thus, conducting successive NE for novel stimuli for familiar and unfamiliar stimuli (i.e., multiple brief exposures) would have provided a more accurate demonstration of participants' degree of Inc. BiN stimulus control.

When analyzing the distribution of participants with varying levels of complexity for Inc. BiN stimulus control, it is important to note that no participants demonstrated Inc. BiN stimulus control for unfamiliar stimuli. Therefore, there are insufficient data to determine whether the highest level of complexity (i.e., higher degrees of Inc. BiN stimulus control for unfamiliar stimuli) would have demonstrated more significant, positive correlations, more variance and predictive value, or more significant differences among reading comprehension measures. Nevertheless, findings of Experiment 2 addressed this limitation by establishing this level of complexity and improving reading comprehension performance.

At the time of Experiment 1, there was no access to conversions from number of correct responses to *WJIV*® standard scores. Due to test items on *WJIV*® test items varying in difficulty as the participant progresses through the subtest, standard scores would have provided a more accurate metric of reading comprehension performance to compare between participants and based on degree of Inc. BiN stimulus control.

Experiment 2

Findings from Experiment 2 suggest that increased complexity of Inc. BiN stimulus control sets the occasion for previously learned relations to join novel stimulus relations when reading. If such is the case, then previously learned relations, or content knowledge, is a critical variable in assessing reading comprehension. In particular, *WJIV*® Passage Comprehension and Reading Vocabulary required some degree of stimulus control for previously learned experiences by requiring the participant to emit a response in the context of a word or sentence. However, participants may have had varying degrees of stimulus control for previously learned experiences, which could have affected increases in reading comprehension performance, especially when considering participants' home environments (Hart & Risley, 2005). For example, Participant 2 demonstrated the smallest increases in mean *WJIV*® performance, which could be due to less exposure to English language experiences at home, as Participant 2 lived in a Spanish speaking household.

In addition, although all participants but one demonstrated increases in correct components emitted in read-do probes for unfamiliar stimuli, results were more variable across participants (Figure 6). The intention of this dependent variable was to measure the acquisition of novel vocabulary words after reading (i.e., "Reading Experience;" Appendix H) functionally by determining whether a participant would be able to not only identify the target stimulus, but also demonstrate the ability to emit a response with the stimulus. However, not all novel vocabulary consists of nouns, as presented in the read-do probe. A more accurate measure of functional vocabulary should be designed to reflect the different forms of novel vocabulary students encounter when reading, such as nouns, verbs, and adjectives.

Another limitation of Experiment 2 was the delivery of a prosthetic reinforcer (i.e., prize) to participants upon achievement of mastery of the intervention. Given that Inc. BiN stimulus control develops as a function of reinforcement for the correspondence between seeing and saying (i.e., seeing the visual stimulus and saying the auditory stimulus), the prosthetic reinforcer created a motivating operation that did not reflect the natural reinforcement of Inc. BiN (Greer, 2020). Conditioning this correspondence under more generalized reinforcement conditions (i.e., vocal praise, point system, or increased exposure to novel stimuli) may have established stronger degrees of Inc. BiN stimulus control and thus, changing its effects on reading comprehension performance. However, given the circumstances of this study, including, but not limited to abrupt switches between virtual and in-person learning and frequent changes in school and classroom schedule and routine, a prosthetic reinforcer was necessary in setting the occasion for the reinforcement value to emerge.

Furthermore, Dyad 1 underwent a different procedure to establish Inc. BiN stimulus control for unfamiliar stimuli. Participants 1 and 2 received repeated probes of a single set to mastery (i.e., "prolonged exposure;" Lo, 2016; Kleinert et al., submitted) for 29 and 27 sessions, respectively, before undergoing MEI across listener and speaker responses (Figure 7). It is currently unknown in the research literature the effect of differing interventions on degree of Inc. BiN stimulus control. However, despite undergoing a different form of intervention initially, both participants still demonstrated increases in reading comprehension performance following the establishment of Inc. BiN stimulus control for unfamiliar stimuli and did these participants did not demonstrate increases of greater scale than the other dyads.

Future Research

Despite such limitations, there exists opportunities for future research to not only address the limitations, but also go beyond the scope of the results of this study. As mentioned previously, Experiment 2's measurement of vocabulary through the *WJIV*® Reading Vocabulary subtest required the use of previously learned experiences and familiarity with the text to establish novel relations. Future studies should build on Helou-Care's (2009) procedure and the findings of the current study to assess the emergence of novel vocabulary after reading a text for early elementary students (i.e., less complex reading content). A similar vocabulary measure to the *WJIV*® Reading Vocabulary subtest could be arranged to control for the previously learned experiences (i.e., content knowledge) by a "Reading Experience" in the form of print stimuli, as opposed to paired visual-print stimuli in the current study (Appendix H).

Future research would also benefit from replicating the current study with modifications to establish differing levels of complexity for Inc. BiN stimulus control, different age groups, and/or varying difficulty in reading content. As a student progresses through grade levels, the reading content increases in length and difficulty. Thus, it would be important to determine whether establishing Inc. BiN stimulus control for unfamiliar stimuli is a level of complexity for BiN that will set the occasion for the formation of novel relations within and between texts. It is possible that more complex levels of BiN, such as actions and functions (Cahill & Greer, 2014) or additional auditory sounds (Lo, 2016), may need to be established in order to respond to more complex texts.

The present study consists of the only procedure at this time that implements an intervention to establish Inc. BiN stimulus control with 10 listener and 10 speaker trials, whereas past research has implemented MEI consisting of 20 trials across four response topographies (Greer et al., 2005) and prolonged, repeated exposure consisting of 20 trials across three response topographies (Lo, 2016; Kleinert et al., submitted). Friedman (2020) measured Inc. BiN stimulus control with 10 trials across three response topographies. Thus, future research should determine whether these varying response opportunities and response topographies (e.g., 10-trial blocks across three response topographies, 20-trial blocks across four response topographies, etc.) have an effect on the strength of Inc. BiN stimulus control following a prolonged time period or on the emergence of more complex language. Additionally, future research should determine if this varying dosage should depend on verbal ability, grade-level, and/or age. For example, students who emit high rates of speaker behavior in non-instructional settings may not need to be assessed in terms of both tacts and intraverbal tacts.

Educational Implications

Results from Experiment 2 demonstrate educationally significant increases in combinatorially entailed assessments, such as WJIV® Passage Comprehension and Reading Vocabulary (Figure 3), but inconsistent increases in read-do probes for unfamiliar stimuli (Figure 6). This implies that as more complex levels of Inc. BiN stimulus control are established, more complex combinatorially entailed relations are formed. Given that students' reading content becomes more complex as they progress through grade levels, stimulus control for Inc. BiN must be continually extended to more complex forms to continue to set the occasion for relations between novel print stimuli and previously learned relations. In other words, the complexity of language development and language acquisition must be included in a student's academic curriculum to ensure continued learning.

Due to variability in previously learned experiences, Catts and Kamhi (2017b) suggest focusing on teaching readers to integrate new knowledge (i.e., novel stimuli presented in the text) with prior knowledge. Regardless of individual verbal ability, reading level, or previously learned experiences (i.e., content knowledge), the ability to join previously learned experiences with novel stimulus relations through reading after establishing complex levels of Inc. BiN presents a potential solution for setting up students for success in general education. In fourth grade, reading instruction shifts from "learning to read" to "reading to learn" (Annie E. Casey Foundation, 2010). "Reading to learn" consists of relating novel stimulus relations with previously learned relations. Once a student can join novel stimulus relations and previously learned relations as a function of increased complexity for Inc. BiN, the student can exponentially increase their exposure to novel stimuli through text and thereby increase their content knowledge and future reading comprehension responses.

Conclusion

In two experiments I studied the relationship between increased complexity for Inc. BiN stimulus control on reading comprehension performance. The present study demonstrates as Inc. BiN stimulus control becomes more complex, reading comprehension measures that varied in reading content and relational responding improved. It is suggested by these findings that increased complexity of BiN stimulus control may affect one's reader-as-own listener repertoire at all stages through the formation of relations between novel stimulus relations and previously learned experiences. Furthermore, these findings build on previous research that emphasizes the importance of Inc. BiN stimulus as a continuum of increasing strength and complexity (Morgan et al., 2020; Friedman, 2020; Kleinert et al., submitted), rather than an all-or-none phenomenon, as represented in past studies (Greer et al., 2005). In other words, continued increases in complexity for Inc. BiN stimulus control sets the occasion for "learning to learn" and thus, prolonged, lifelong learning.

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Appendix A

Preconstructed Inc. BiN Data Sheet for Experiment 1

Participant Name: ______________________ **DATE:** ____________

STIMULI		**EXPERIENCE** Time:		**NAMING PROBE** Time: __________	
Visual	Name	Tact Presentations		Listener	Speaker
	Otto			1.	1.
				2.	2.
	Tito			3.	3.
				4.	4.
	Sam			5.	5.
				6.	6.
	Regina			7.	7.
				8.	8.
	Lars			9.	9.
				10.	10.
		# ECHOICS		**# CORRECT**	
				% IOA: ____________	

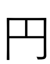
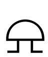
Comments: ____

Participant Name: ______________________ **DATE:** ____________

STIMULI		**EXPERIENCE** Time:		**NAMING PROBE** Time: __________	
Visual	Name	Tact Presentations		Listener	Speaker
	Otto			1.	1.
				2.	2.
	Tito			3.	3.
				4.	4.
	Sam			5.	5.
				6.	6.
	Regina			7.	7.
				8.	8.
	Lars			9.	9.
				10.	10.
		# ECHOICS		**# CORRECT**	
				% IOA: ____________	

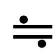
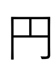
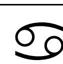
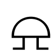
Comments: ____

Participant Name: ______________________ **DATE:** ____________

STIMULI		**EXPERIENCE** Time:		**NAMING PROBE** Time: __________	
Visual	Name	Tact Presentations		Listener	Speaker
	Naymit			1.	1.
				2.	2.
	Teesup			3.	3.
				4.	4.
	Magoob			5.	5.
				6.	6.
	Dugle			7.	7.
				8.	8.
	Gribat			9.	9.
				10.	10.
		# ECHOICS		**# CORRECT**	
				% IOA: ____________	

Comments: ____

Participant Name: ______________________ **DATE:** ____________

STIMULI		**EXPERIENCE** Time:		**NAMING PROBE** Time: __________	
Visual	Name	Tact Presentations		Listener	Speaker
	Naymit			1.	1.
				2.	2.
	Teesup			3.	3.
				4.	4.
	Magoob			5.	5.
				6.	6.
	Dugle			7.	7.
				8.	8.
	Gribat			9.	9.
				10.	10.
		# ECHOICS		**# CORRECT**	
				% IOA: ____________	

Comments: ____

Appendix B

Reading Comprehension State Learning Standards Assessed during *i-Ready®* Reading diagnostic

Domain	Code	Standard Description
Reading Literature Text: Key Ideas and Details	RL.1.1	Ask and answer questions about key details in a text.
	RL.1.2	Retell stories, including key details, and demonstrate understanding of their central message or lesson.
	RL.1.3	Describe characters, settings, and major event(s) in a story, using key details.
Reading Liteature Text: Craft and Structure	RL.1.4	Identify words and phrases in stories or poems that suggest feelings or appeal to the senses.
	RL.1.6	Identify who is telling the story at various points in a text.
Reading Literature Text: Integration of Knowledge and Ideas	RL.1.7	Use illustrations and details in a story to describe its characters, setting, or events.
	RL.1.9	Compare and contrast the adventures and experiences of characters in stories.
Reading Informational Text: Key Ideas and Details	RI.1.1	Ask and answer questions about key details in a text.
	RI.1.2	Identify the main topic and retell key details of a text
	RI.1.3	Describe the connection [cause and effect; sequence] between two individuals, events, ideas, or pieces of information in a text.
Reading Informational Text: Craft and Structure	RI.1.4	Ask and answer questions to help determine or clarify the meaning of words and phrases in a text.
	RI.1.5	Know and use various text features (e.g., headings, tables of contents, glossaries, electronic menus, icons) to locate key facts or information in a text.
	RI.1.6	Distinguish between information provided by pictures or other illustrations and information provided by the words in a text.
Reading Informational Text: Integration of Knowledge and Ideas	RI.1.7	Use the illustrations and details in a text to describe its key ideas.
	RI.1.9	Identify basic similarities in and differences between two texts on the same topic (e.g., in illustrations, descriptions, or procedures).
Language Vocabulary Acquisition and Use	L.1.4.A	Use sentence-level context as a clue to the meaning of a word or phrase.
	L.1.5.A	Sort words into categories (e.g., colors, clothing) to gain a sense of the concepts the categories represent.
	L.1.5.B	Define words by category and by one or more key attributes (e.g., a duck is a bird that swims; a tiger is a large cat with stripes).

L.1.5.C	Identify real-life connections between words and their use (e.g., note places at home that are cozy).
L.1.5.D	Distinguish shades of meaning among verbs differing in manner (e.g., look, peek, glance, stare, glare, scowl) and adjectives differing in intensity (e.g., large, gigantic) by defining or choosing them or by acting out the meanings.
L.1.6	Use words and phrases acquired through conversations, reading and being read to, and responding to texts, including using frequently occurring conjunctions to signal simple relationships (e.g., because).

Appendix C

Preconstructed Inc. BiN Data Sheet for Experiment 2

Participant Name: ____

STIMULI SET #____		**PROBE**		**PROBE**		**PROBE**		**PROBE**	
		Date: _______		Date: _______		Date: _______		Date: _______	
Visual	Name	Listener	Speaker	Listener	Speaker	Listener	Speaker	Listener	Speaker
		1.	1.	1.	1.	1.	1.	1.	1.
		2.	2.	2.	2.	2.	2.	2.	2.
		3.	3.	3.	3.	3.	3.	3.	3.
		4.	4.	4.	4.	4.	4.	4.	4.
		5.	5.	5.	5.	5.	5.	5.	5.
		6.	6.	6.	6.	6.	6.	6.	6.
		7.	7.	7.	7.	7.	7.	7.	7.
		8.	8.	8.	8.	8.	8.	8.	8.
		9.	9.	9.	9.	9.	9.	9.	9.
		10.	10.	10.	10.	10.	10.	10.	10.
TOTAL CORRECT									
TACT NE		% IOA: ______________		% IOA: ______________		% IOA: ______________		% IOA: ______________	
Date/Time: ______________		% TF: ______________		% TF: ______________		% TF: ______________		% TF: ______________	

Comments: ____

____

____

Appendix D

Characteristics of Leveled Texts (Pinnell & Fountas, 2011; p. 150, 154-155)

Characteristic	Level F	Level H
Language and Literary Features	• Amusing or engaging one-dimensional characters • More literary stories and language Texts with familiar settings close to children's experience • Both simple and split dialogue, speaker usually assigned • Some longer stretches of dialogue Simple sequence of events • A few simple elements of fantasy	• Amusing or engaging one-dimensional characters • Some stretches of descriptive language • Some texts with settings that are not typical of many children's experience • Almost all dialogue assigned to speaker • Full variety in presentation of dialogue • Multiple episodes taking place across time • Simple, traditional elements of fantasy
Sentence Complexity	• Some long sentences (more than ten words) with prepositional phrases, adjectives, and clauses • Some sentences that are questions in simple sentences and in dialogue • Some complex sentences with variety in order of clauses • Sentences with prepositional phrases and adjectives • Use of commas to set words apart • Some compound sentences conjoined by "and"	• Some long sentences (more than ten words) with prepositional phrases, adjectives, and clauses • Some sentences that are questions in simple sentences and in dialogue • Some complex sentences with variety in order of clauses, phrases, subject, verb, and object • Variation in placement of subject, verb, adjectives, and adverbs
Vocabulary	• Most vocabulary words familiar to children and likely to be used in their oral language • Variation in use of words to assign dialogue in some texts	• Most vocabulary words familiar to children and likely to be used in their oral language • Some content-specific words introduced, explained, and illustrated in the text • Wide variety in words used to assign dialogue to speaker

Words	• Mostly one- to two-syllable words • Some three-syllable words • Plurals, contractions, and possessives • Many high-frequency words • Many words with inflectional endings • Mostly words with easy predictable letter-sound relationships and spelling patterns (decodable) • Some complex letter-sound relationships in words • Some words used multiple times in different language structures • Variety of easy spelling patterns Easy contractions	• Mostly one- to two-syllable words • Some three-syllable words • Plurals, contractions, and possessives • Wide range of high-frequency words • Many words with inflectional endings • Some complex letter-sound relationships in words • Some complex spelling patterns • Multisyllable words that are generally easy to take apart or decode • Some easy compound words

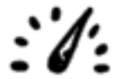
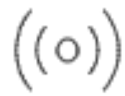
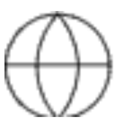
Appendix E

Examples of Target Stimuli Sets to Establish Inc. BiN for Unfamiliar Stimuli (Sets 1, 2, 3, 4, and 5)

Set 1	Set 2	Set 3	Set 4	Set 5
グ		ネ	⌘	승
Nalpur	Reesay	Vokev	Yimello	Vesla
も	‡	に	Ξ	사
Foydot	Nekmit	Sumie	Eesup	Zarnesh
ゆ	♎	㊤	ぺ	グ
Olead	Duvat	Dacin	Wensad	Mipool
尽	夫	ж	≑	⌥
Zygan	Koogen	Potil	Boameg	Folo
仕	宮		あ	
Syopp	Enling	Gaglo	Insoot	Choobili

Appendix F

Examples of Target Stimuli Sets for Read-Do Probes (Sets A, B, C)

Set A	Set B	Set C
 Clop	 Jop	 Hok
 Wiv	 Blim	 Mibe
 Frum	 Pame	 Ras
 Mab	 Tud	 Crut
 Gute	 Wike	 Flaz
 Sen*	 Nex*	 Pid*

Note: (*) denotes stimuli not directly exposed to participants during the novel Reading Experience and represent the measure of reading comprehension by exclusion

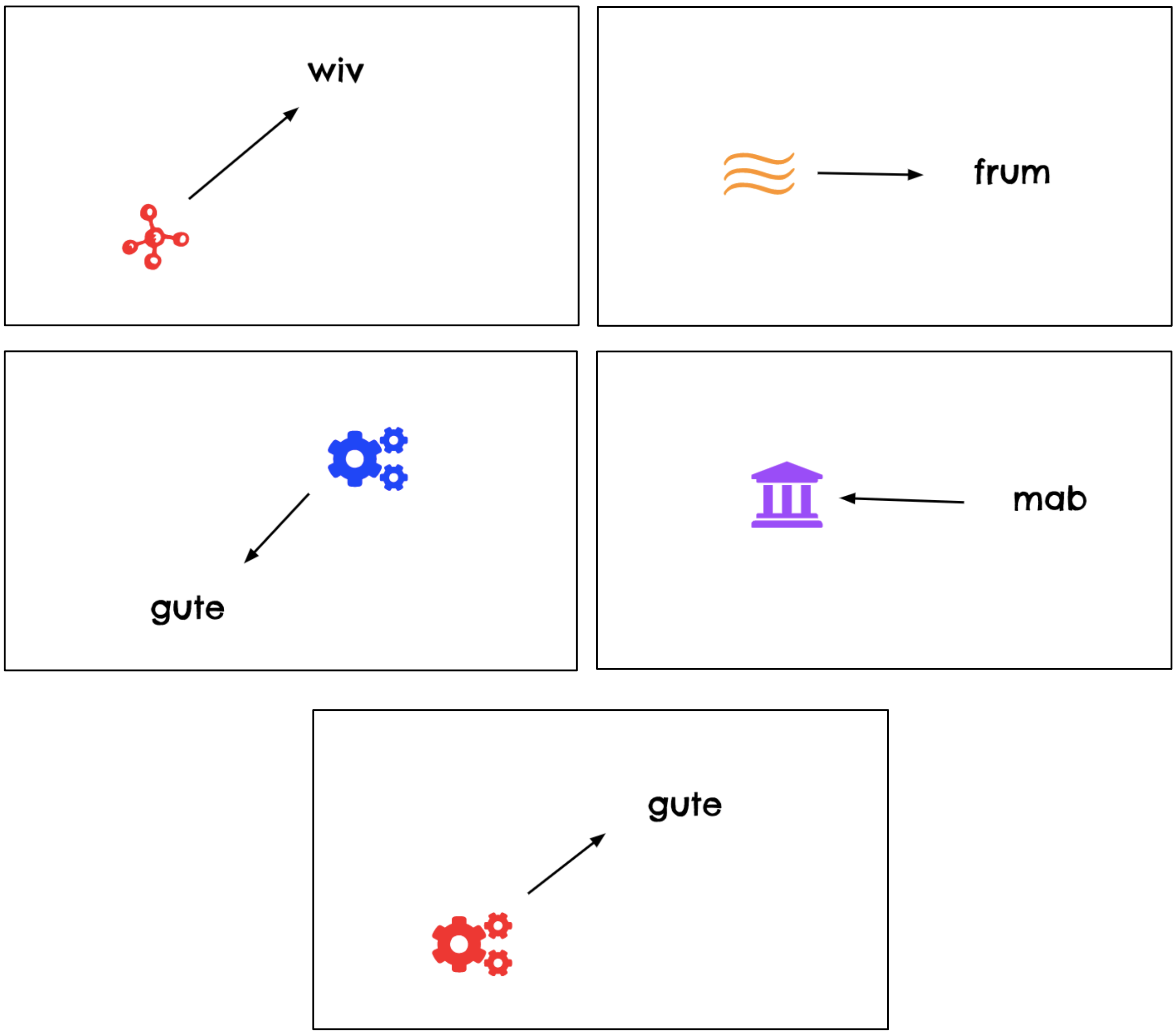
Appendix G

Example of Rubric for Passage Comprehension Probe (Set H1)

	Question	Answer(s)
Fiction: Cell Phone Santa		
1	Why was this year's Christmas list different from previous years?	She only wanted one thing; She used to have long Christmas lists every year, but this year she just had one thing
2	Why does Molly's mom think she doesn't need a cell phone?	Because she's only 10
3	Why does Molly think she needs a cellphone?	She says that everybody she knows has cell phones
4	How does Molly's mom say she can talk to her friends?	By calling them on the house phone and inviting them over
5	Why was Molly confused about getting a cell phone case for Christmas?	She did not have a cell phone.
Non-Fiction: The Water Cycle		
1	What does the sun turn water into?	Water vapor
2	What is water vapor?	A gas that cannot be seen
3	How does the water vapor turn into liquid again?	Condensation; the sky cools the water to turn into a liquid
4	Where does all of the melted snow go?	The oceans and lakes
5	How does the water start to evaporate?	The sun heats the water

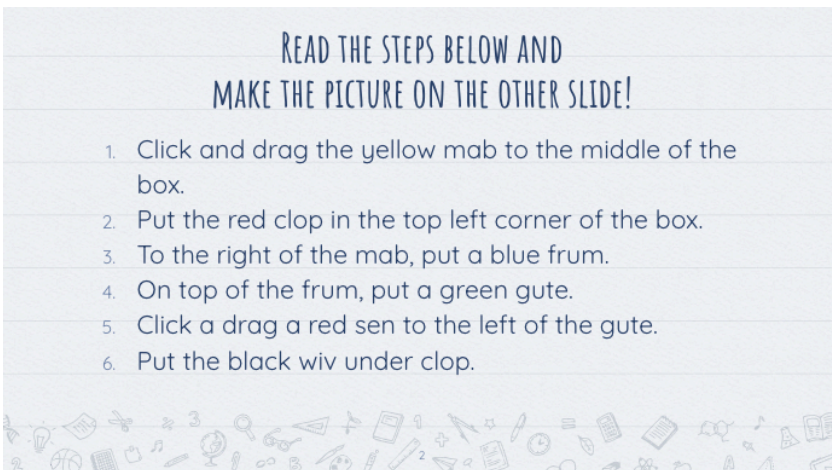
Appendix H

Example of "Reading Experience" (Set A) Presented before Read-Do Probes



Appendix I

Example of Read-Do Probe for Set A



Appendix J

Example of Scoring Rubric for Read-Do Probe (Set A)

Step	Component
1. Click and drag the yellow mab to the middle of the box.	Mab
2. Put the red clop in the top left corner of the box.	Clop
3. To the right of the mab, put a blue frum.	Frum
	Right of mab
4. On top of the frum, put a green gute.	Gute
	Top of frum
5. Click a drag a red sen to the left of the gute.	Sen
	Left of Gute
5. Put the black wiv under clop.	Wiv
	Under clop

Appendix K

Assignment of Target Stimuli Sets to Establish Inc. BiN Stimulus Control across Participants

Dyad 1		Dyad 2		Dyad 3	
P1	P2	P3	P4	P5	P6
1	2	3	4	5	6
4	5	1	6	3	7
5	6	7	3	8	1
2	1	8	5	6	4
6	3	4	7	1	8
7	8	6	12	14	2
8	4	2	1	10	15
3	7	14	11	13	3
11	9	5	15		12
9	10		14		14
10	11		2		
14	12				
12	15				
15					
13					