Establishment of Increased Stimulus Control for Bidirectional Naming Increased Stimulus Control for Other Derived Relations in 20- to 40-Month-Old Toddlers

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Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy under the Executive Committee of the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY

2020
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Researchers across domains of behavior analysis agree that complexities of language acquisition can be defined by the degree to which an individual acquires language relations in the absence of direct training. In a series of studies, I examined the role of voluntary echoic responses on the onset of bidirectional naming (BiN) and the implications of the naming continuum, defined by accuracy of listener and speaker responses for familiar stimuli, on the emergence of untrained, language relations. Using a group descriptive analysis, I tested the correlations between storybook naming experiences and accuracy of listener (selection) and speaker (tact) responses across 24 toddlers, aged 20- to 37-months-old. During the naming experience, I measured voluntary production of the target stimulus (saying the target word). During the naming probe, I measured accuracy of untaught listener and speaker responses. While there were not significant associations between voluntarily saying the target stimulus and the accuracy of listener/speaker responses and voluntary responses remained low across 3 naming experiences, there were significant associations among accuracy of listener/speaker responses across the 3 experiences. Listener responses significantly increased across the three experiences, suggesting the emergence of unidirectional naming (UniN); however, speaker responses remained low. In Experiment II, I tested the effects of echoic clarity (phonemic responses that each participant demonstrated) on accuracy of untaught listener/speaker responses using storybook naming experiences. Data remained consistent in suggesting that UniN was present, but echoic clarity was not functionally related to measures of BiN. In Experiment III, I tested the effects of temporal proximity of visual
and auditory stimuli on voluntary echoics and accuracy of listener/speaker responses using Successive Naming Experiences with Novel Stimuli (SNENS). This consisted of presenting auditory and visual stimuli simultaneously or with a one-second delay between the visual and auditory stimuli. Data remained consistent across participants in showing that the accuracy of listener/speaker responses was not dramatically affected by temporal proximity of visual and auditory stimuli. Serendipitous findings of this experiment suggested that the joining of listener and speaker responses may be required for acquisition of more complex derived relations. I conducted Experiment IV to address the unanticipated findings of the pilot study, by testing if a functional relation exists between the naming continuum and the emergence of other arbitrarily applicable derived relations (AAR). Four of the 6 participants demonstrated mastery of mutual and combinatorial entailment relations following increased degrees of BiN, while 2 of the participants demonstrated increases in combinatorial entailment relations. Results suggested a functional relation exists between the accuracy of untaught listener/speaker responses for word-object relations and the emergence of other AAR. I discuss these findings with regards to the essential stimulus control for untaught language relations as a history of reinforcement for correspondence.
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ACKNOWLEDGEMENTS

To everyone I have encountered along the way, you have influenced me more than you will ever know. Each step of this journey lead me to where I am today. I am forever grateful for your support and encouragement. We did it!

First, I would like to thank my dissertation committee members for their time and insight during each step of this process. Dr. Greer, Dr. Fienup, Dr. Wang, Dr. Arora, and Dr. Fryling, thank you, your guidance and feedback been invaluable, and I am honored to learn from such incredible scholars. Dr. Greer, simply thank you would not encompass the inspiration, perseverance, and patience you have shown me. I am truly proud to have had you as my dissertation sponsor and mentor! Dr. Fienup, thank you for your dedication to my dissertation studies and for shaping my writing and graphical skills. Dr. Wang it has a been a privilege to have you as my committee chair, thank you for making the remote defense process as easy as possible! Dr. Arora and Dr. Fryling, thank you for offering your feedback as outside readers, it was a privilege to receive your feedback during the defense process.

To my outstanding professors and mentors, this dissertation was possible because of you. Dr. Dudek, thank you for everything. Thank you for assuring me that I could do this three years ago. Dr. Delgado, thank you for being an incredible role model over the years. Dr. Jahromi, thank you for the invaluable feedback for my first study. I am endlessly grateful!

To my forever friends: Madeline F. and Megan F., thank you to CABAS® for bringing you into my life 5 years ago. This dissertation would not have been possible without your daily reminders and encouragement. Thank you for your hours spent on the phone, FaceTime, and Zoom listening to me practice the same presentations! Maddy- thanks for answering my endless
questions as I navigated this year. I am indebted to you and am excited to finally spend time with you!

To my CABAS® cohort: Brittany, Victoria, Faheema, and Katherine, I am so lucky to have worked alongside such an intelligent group of women. I am so proud of us and this dissertation would not have been possible without you. Brittany and Victoria, I am so thankful to have had you as neighbors the last few years. Katherine, thank you for being a shoulder to lean on during the tough and the exciting times. I am so proud of you all!

To the staff at the Fred S Keller School Yonkers campus, thank you for the dedication and insight as I navigated through this dissertation. It has been my pleasure to work alongside such intelligent and collaborative group of people. Dr. Jeanne Speckman and Dr. Cesira Farrell thank you for your guidance and input which made this dissertation possible. Dr. Stavra Romas, I am so fortunate to have worked alongside and learned from you. Victoria D., I am indebted to you! You have contributed an incredible amount of time and dedication both as my colleague and as my friend. Thank you for helping me with data collection and for being there across the highs and the lows the last three years. Katherine G. and Cheryl W., I cannot begin to thank you for your time and dedication this past year. Thank you for helping me endlessly and thank you for making me laugh! Amanda D. and Ellis, I got so lucky to work alongside you. Thank you for your dedication and time as I completed my studies. I am so fortunate to work with such a motivating and incredible women and teachers.

To every student I have had the privilege to work with past and present, thank you for showing me unwavering patience, kindness, and caring. Because of you, I have learned what it means to be a great teacher. Continue to shine your light!
To all my friends in NYC, Florida, and elsewhere, no matter how much time went by, you were always there to support me. I look forward to finally having more time to spend with all of you. Taylor, Danielle, Nicole, Jackie, Steph, Haley, and everyone, you mean so much to me thank you for the laughs, memories, and “mental breaks” over the years. Thank you all for being there along the way and celebrating with me each step of the way. I am so grateful for you all!

Thank you to my grandparents, parents and siblings (dogs too!) for loving me unconditionally through the excitement and the challenges. Mom and Dad, thank you for being my biggest fans. Thank you for being excited for all of the accomplishments along the way, big or small, regardless of what they were or what they meant. Thank you for the sacrifices you made along the way and providing us the opportunities to do anything and everything we set our hearts out to do. I could not have done this without you. Jake and Jessie, you are up next, and I am excited to see the wonderful things you will do! Max and Sam, thank you for the infinite cuddles and love!
DEDICATION

To all of the families and children who I met along this journey, thank you.

This one is for you!
CHAPTER I

INTRODUCTION AND REVIEW OF THE LITERATURE

Introduction

There is growing interest in identifying how children rapidly acquire new vocabulary and more complex language repertoires, across developmental and psychological domains (Bloom, 2000; Crystal, 2006; Gilic & Greer, 2011; Hayes, Barnes-Holmes, & Roche, 2001; Hall & Chase, 1991; Kenneally, 2007; Morgan, 2018). In behavior analysis, this phenomenon is known as naming, initially proposed by Horne and Lowe (1996; Greer, Stolfi, Chavez-Brown, & Rivera-Valdes, 2005; Greer & Longano, 2010; Greer & Speckman, 2009). Horne & Lowe (1996) defined naming as a basic behavioral unit, that which resulted in untaught higher order bidirectional relations. Horne and Lowe proposed that the emergence of naming resulted in the following, 1) emergent categorization of behaviors and 2) incidental emergence of listener and speaker responses. For children without any native disabilities, Horne and Lowe reported that this phenomenon emerges around age three; however, Gilic and Greer (2011) found that it can emerge as a function of instructional histories and experiences closer to age two.

Once naming emerges, children can experience a word-object relation as a listener (e.g. mother says “here is your car”) and without any direct training, emit the response under the same conditions as a speaker (e.g. “car”), and vice versa. The emergence of naming, as a result of instructional histories and experiences, may be responsible for the commonly labeled “vocabulary explosion” (Crystal, 2006; McGuiness, 2005; Hart & Risley, 1995). Miguel (2016) added the qualifier bidirectional to the concept of naming (BiN) to emphasize that the bidirectional operant occasions both speaker and listener behaviors, originally proposed by
Horne & Lowe, 1996). Subsequently, we refer to the joining of listener and speaker repertoires, naming, as bidirectional naming, or BiN.

Children who demonstrate the presence of BiN can acquire more complex repertoires and verbal development cusps and capabilities such as observational learning (Greer, Singer-Dudek, & Gautreaux, 2006) as well as BiN joins print stimulus control (Gentilini, 2019; Helou-Care, 2008). Researchers argue that the emergence of BiN also serves as the stimulus control for more complex verbal behavior, including emergence of relational frames (Hayes et al., 2001; Greer & Longano, 2010). That is, once one the stimulus control for bidirectional operants is acquired (listener and speaker responses), it sets the occasion for the acquisition of more complex correspondence between stimulus relations to emerge (Hayes et al., 2001).

There is extensive literature in the field of behavior analysis on BiN, how to establishment it if it does not emerge incidentally (Gilic & Greer, 2011; Hranchuk, Greer, & Longano, 2018; Kleinert, 2018; Lo, 2016), sources of reinforcement responsible for its onset (Longano & Greer, 2015; Cao & Greer, 2019), and educational implications following its onset (Hranchuk et al., 2018; Helou-Care, 2008). Despite this extensive literature, there are few studies examining the relation between voluntary echoics and the emergence of BiN. Longano & Greer (2015) found a correlation exists between increased voluntary echoics during caregiver-delivered experiences of word-object relations and the emergence of BiN for toddler-aged participants. To further investigate this correlation, Cao and Greer (2019) investigated the effects of echoic training for monolingual students on the establishment of BiN in a second language. These findings suggested a functional relation between echoic trainings and the onset of BiN.

The purpose of the present study was to examine the relations among variables associated with measures of BiN for toddler-aged participants. In a group descriptive analysis, I evaluated
the correlations between opportunities to voluntarily say the name of the target stimulus during naming experiences for novel stimuli (word-object relations) using an attempted storybook approach and the onset of BiN. In Experiment II, I further examined the storybook naming experience to test if a functional relation exists between echoic clarity, defined by participant’s phonemic correspondence to a target auditory stimulus, and the onset of BiN. I conducted a third experiment to test whether successive novel naming experiences, using repeated pairing of auditory and visual stimulus (tact experience), was a more effective procedure for inducing BiN I also examined the role of temporal proximity of visual and auditory stimuli on the accuracy of untrained listener and speaker responses. Secondary findings of this study lead to further research questions tested in Experiment IV. In Experiment IV, I sought to determine where on the continuum of BiN children acquire other, untrained language relations.

Findings of the present studies significantly add to the body of literature surrounding untaught language relations across domains of behavior analysis. By isolating the variables associated with consecutive naming experiences and controlling for echoic clarity, I demonstrated that acquisition of joint stimulus control across listener and speaker response via a storybook may require more complex verbal developmental. In conducting successive novel naming experiences, I addressed the limitations identified in the first two studies. Serendipitous findings suggested the emergence of untrained language relations suggesting the link between BiN and the onset of complex language relations. The following visual provides an overview of the scope and sequence of the studies, followed by a review of relevant literature.
### I: Descriptive Analysis of Accuracy of Listener and Speaker Responses using a Storybook Naming Experience

<table>
<thead>
<tr>
<th>Methods</th>
<th>Findings</th>
</tr>
</thead>
</table>
| Storybook naming experience is an attempted, laboratory-simulated approach of a natural encounter between a caregiver and a child | • Did not have consistent opportunities to echo during experience  
• Delayed opportunity to voluntarily say target stimulus → previous studies always presented auditory in proximity to visual stimulus  
• Demonstrated Unidirectional Naming (listener), but speaker responses remained low….why?  
• Suggests echoic (proximate) may play important role but may be related to echoic correspondence of auditory stimulus  
  o “Koop” emitted but not “Lavern” → suggested role of echoic clarity on accuracy of listener/speaker responses |
| • Group descriptive analysis (N=24)  
• **Independent Variable (IV):** Successive Naming Experiences with Identical Storybook Stimuli  
• **Dependent Variable (DV):** voluntarily saying the name of target stimulus, accuracy of listener/speaker responses  
• **Research Question (RQ):** Are there significant differences in correct listener and speaker responses across the three experiences? Is the storybook naming experience an effective method for measuring degrees of BiN? | |

### II: Experimental Comparison of Echoic Clarity on Accuracy of Listener and Speaker Responses

<table>
<thead>
<tr>
<th>Methods</th>
<th>Findings</th>
</tr>
</thead>
</table>
| • Single case ABAB Reversal design  
• 4 typically-developing toddlers  
• **IV:** manipulation of phonemic responses that each child demonstrated  
  o A=FULL; B=Partial  
• **DV:** voluntarily saying the name of target stimulus, accuracy of listener/speaker responses under two conditions  
• **RQ:** What is the role of echoic clarity on the accuracy of listener/speaker responses using consecutive storybook naming experiences? | • No reliable difference in accuracy of listener/speaker responses between partial and full conditions  
• Listener responses increased within each phase and speaker responses were variable (Participant D demonstrated BiN)  
• Echoic correspondence not related to accuracy of listener/speaker responses  
• Data suggest echoic clarity is not an explanation for low speaker responses seen in Experiment I, why is speaker not joining? |

### Discussion

1. Voluntarily saying the name of the target stimulus functioning to join listener/speaker responses is NOT likely to happen with other auditory stimulus occurring between presence of auditory and visual stimuli.  
2. In the absence of a proximate, voluntary response opportunity, listener responses emerging but not speaker responses.  
3. At this point in verbal development the book is not an effective procedure. How do kids learn names of things from book?  
4. Experiment II eliminates the potential for the ability to produce words as a variable to consider when assessing for BiN  
5. At this point in the target participants verbal development, the storybook naming experience did not work to induce BiN.
### III: Effects of Temporal Proximity of Auditory and Visual Stimuli on Accuracy of Listener and Speaker Responses

**Methods**
- Single case, alternating treatments design
- 6 toddler-aged participants
- IV: Successive Naming Experiences with Novel Stimuli (SNENS)
  - Simultaneous presentation of visual and auditory
  - Delayed presentation of auditory (1 second)
- DV: voluntary echoics, accuracy of listener/speaker responses
- RQ: What is the role of temporal proximity of visual and auditory stimuli on the demonstration of BiN?

**Findings**
- Results were idiosyncratic across participants (Unidirectional naming, some transformation of stimulus function to speaker)
- Participants with the strongest degree of BiN responded higher in delayed condition
- Serendipitous findings: few of the participants could go from component to category in the absence of training (e.g., given picture of tuba, tact = “instrument”)
- Suggestive of relation between BiN and bidirectional relations (Frank, 2018; Morgan, 2018)

### IV: Functional Relation between Bidirectional Naming (BiN) and Other Arbitrarily Applicable Relations (AAR)

**Methods**
- Single case, multiple probe design
- 6 toddler-aged participants
- IV: Establishment of BiN using SNENS or Single Naming Experience with Repeated Probe (SNERP)
- DV: accuracy of derived relations (Morgan, 2018), accuracy of listener/speaker responses
- RQ: Is there a functional relation between accuracy of untrained listener and speaker responses and other AAR?

**Findings**
- Transformation of stimulus function (TSF) from listener to speaker functioned to increase accurate, untrained relations
- Four participants with stronger degrees of TSF, or those who demonstrated BiN responded quicker acquisition of AAR
- Results suggest that BiN not a prerequisite for other AAR; rather, the reinforcement for correspondence across listener/speaker sets the occasion for other AAR to emerge.
- Suggestive of reinforcement for correspondence as a possible source of reinforcement for emergent language relations (Greer, 2020).

### General Discussion
1. Findings of Experiment III suggest potential functional relation between BiN and other AAR in the absence of a correct speaker response, participants’ prior stimulus control participated in categorical responses (e.g., “instrument”)
2. In Experiment IV, four of six participants with UniN, who demonstrated some untrained stimulus class relations (mutual entailment) acquired AAR as a function of acquisition of TSF across listener and speaker responses (the emergence of BiN) for familiar, novel stimuli
3. Findings further support literature on BiN and other AAR by adding that the stimulus control previously demonstrated to establish BiN function to condition reinforcement for correspondence for other AAR and suggest that correspondence is a possible reinforcer for emergent language relations (Greer, 2020).
In this chapter, I will first review relevant literature on theoretical accounts of language learning with particular focus on incidental language learning and behavior-analytic accounts of language acquisition including stimulus equivalence (SE), Relational Frame Theory (RFT), and Verbal Behavior Developmental Theory (VBDT). I will then focus on Bidirectional Naming (BiN), sources of reinforcement responsible for its onset, BiN as a dependent variable, and the extensive implications following its onset, followed by relevant literature on order of stimulus presentation for acquisition of novel repertoires. Finally, I will review literature demonstrating relations between BiN and other language relations, such as derived relations (Morgan, 2018) and basic concepts (Frank, 2018).

**Theories of Language Learning**

Research on language acquisition has focused on its development across structure and function (Crystal, 2006; Greer & Ross, 2008; Greer & Speckman, 2009; MacCorquodale, 1970; Stemmer, 1990). The linguistic perspective of language development proposes theories related to the structure, or form, of language (Crystal, 2006; Chomsky, 1959; Chomsky & Place, 2000; MacCorquodale, 1970). According to cognitive linguistics, studying how a child learns a language, the meaning of words (word-object relations), and listener and speaker responses is a critical developmental stage. Understanding how a child learns a language, learns new words, and the meaning of words and how they use the words within their environment as an effective listener and speaker is a primary focus across the theories of language acquisition. Theories of word learning discussed herein are Fast Mapping (Carey & Bartlett, 1978), Stimulus Equivalence (Sidman, 1994), Relational Frame Theory (Hayes et al., 2001), and Verbal Behavior Developmental Theory (Greer & Ross, 2008; Greer & Speckman, 2009).

**Fast Mapping**
Cognitive linguistics focus on the process of fast mapping to explain the phenomenon of learning new language (Carey & Bartlett, 1978). This developmental concept in cognitive psychology refers to the process of new language acquisition based on word-object relations and “referent selection” and “referent retention” (Carey & Bartlett, 1978). In the relevant literature, fast mapping is considered rapid, associative word learning process by which one acquires and maintains new words following minimal exposure (Carey & Bartlett, 1978; Heibeck & Marckman, 1987). Fast mapping may be a possible explanation for the impressive rate at which young children acquire new words (Carey, 1978).

Early research on fast mapping by Carey and Bartlett (1978) suggested that children can acquire some information about the meaning of a word through contextual information, such as how the word is used in a sentence. In the pilot study, researchers presented children with a novel color word, “chromium”, using statements of contrast such as “bring me the chromium one. Not the red one, the chromium one” (Carey & Bartlett, 1978, p 2). According to Carey and Bartlett (1978), following a single exposure to a new word with novel phonological components and semantic value, a child creates preliminary word-meaning relations, or maps (Carey & Bartlett, 1978). These word-meaning relations emerge following a single exposure in the absence of direct training. There is little evidence reported in the literature on various topographies of experiences and joint attention (Greer & Ross, 2008) required for these word-object relations to emerge. However, most research on fast mapping appears to only test receptive, or listener, responses. Carey and Bartlett (1978) suggested that fast mapping refers to the initial encounter with a new word, although the participant could not “remember” the name of the word (p 2).

Researchers have focused on fast mapping with varying ages and populations of children, both neurotypically developing and children with specific language impairments.
Interestingly, in Carey and Barlett’s (1978) study, three-year-old participants did not reliably demonstrate hypothesized effects of fast mapping (Swingly, 2010); however, Horst & Samuelson (2010) expanded on these findings and found that 24-month-old participants demonstrated fast mapping following single exposures but demonstrated limited recall. Several studies related to fast mapping revealed that children as young as nine-months-old can acquire phonological forms for words they frequently experience (Jusczyk & Hohne, 1997); however, the social-pragmatic components of word learning are acquired at more advanced stages of development (Bloom, 2000). Swingly (2007) found that given exposure to words used in context facilitates later acquisition of such words for 16-month-old participants. Further research findings suggest that by the age of 24 months, a child can demonstrate acquisition of selection responses related to a novel word, following exposures to that word (Yuan & Fisher, 2009); however, is limited to receptive skills (listener). Dollaghan (1987) tested the effects of similar procedures across neurotypical students and those with specific language impairments to teach new words as selection responses. While there were no significant differences across the two groups in their selection responses following single exposures, the neurotypical participants emitted increased speaker responses related to the novel word compared to those participants with specific language impairments.

Early research on fast mapping isolated various cues, such as social cue, or eye gazing, linguistic or semantic cues to measure the emergence of word-meaning relations (Carey & Bartlett, 1987). Findings suggested that one cue may be sufficient for rapid, associative word learning to occur; however, findings were limited to immediate effects. Controversy across theories of language acquisition focus on whether words learned via aforementioned practices are acquired, and learned, or simply recalled. Researchers found that children correctly
responded to “chromium” several days following exposure and in another study, children recalled words one month following exposures (Carey & Bartlett, 1978; Markson & Bloom, 1997). Further, response criteria for presence of fast mapping is not clearly reported in the literature and procedures for test of recall are conducted almost immediately following exposures, suggesting fast mapping may be a test of word reproduction versus word acquisition. Further, empirical research on fast mapping does not manipulate environmental conditions which occasion novel use of target words (e.g. using the word in a sentence with a caregiver; Braisby, Dockrell, & Best, 2001).

**Stimulus Equivalence (SE)**

Stimulus Equivalence (SE) suggests that language can be acquired through relations derived across three stimuli. Stimulus equivalence as a phenomenon occurs when three or more stimuli become functionally interchangeable. Research conducted by Sidman (1971) demonstrated the emergence of equivalence classes for textual responses. Sidman (1990) proposed SE to define equivalence classes as sets of three or more physically dependent stimuli which demonstrate the following relations: reflexivity (A), symmetry (B), and transitivity (C).

The aforementioned relations define unique equivalence relations that are established across a minimum of three stimuli that are of the same stimulus class and are used to test for the presence of untrained relations (Hall & Chase, 1991; Hayes & Hayes, 1989; Stromer, Mackay, & Stoddard, 1992). Reflexivity is present when a stimulus is matched to an identical stimulus (A=A). An example of this relation occurs when a child matches a picture of a dog to an identical picture of a dog following direct training. Symmetry can be characterized as reversibility of trained responses (e.g. if A=B is trained, the B=A emerges). If a picture of a dog to a real dog is trained as a response, a student who demonstrates the presence of symmetry
relations will then identify that a real dog matches to a picture of a dog without direct training. Finally, transitive equivalence relations are demonstrated when two stimulus-stimulus relations are trained and third, untrained relation emerges (e.g. if A=B and B=C are trained, then A=C emerges). That is, the student is taught that a picture of a dog matches to the real dog, and a real dog matches to the spoken word “dog”, transitive relations are evident when the child then selects a picture of a dog when presented with the spoken word “dog”. In terms of acquisition of verbal repertoires, SE assist in the acquisition of multi-modal novel operants (e.g. listener and speaker responses).

**Relational Frame Theory (RFT)**

Relational Frame Theory (RFT) is a behavior analytic account of language acquisition and can be considered an extension of the verbal behavior theory proposed by Skinner (1957; Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000; Dymond & Barnes, 1995; Hayes et al., 2001; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeady, 2000). The goal of RFT is to provide a description of behavior-environment relations which result in relational responding. According to Chase & Danforth (1991), RFT emerges when explicit conditioning of listener behavior involves contingencies regarding arbitrary stimulus relations, most likely related to equivalence classes. Verbal behavior involves arbitrary relations across listener and speaker responses, and as such, RFT discusses the establishment of arbitrary relations via a history of reinforcement for responding under specific conditions (Chase & Danforth, 1991).

RFT proposes that given adequate training, one can respond to relations related to physical properties of two or more stimuli, as such RFT includes equivalence relations of SE (Hayes et al., 2001). However, such relations are bound by formal properties, or nonarbitrary relations, of the relevant stimuli and as such cannot be considered derived relational responding.
According to Hayes et al. (2001), “relating” is defined by responding to one stimulus in terms of another. A relational response is one that is not purely dependent on physical properties of the stimuli (Hayes et al., 2001, p. 25). That is, the response is brought under appropriate relational context and is arbitrarily applicable or controlled by contextual cues. In comparing SE and RFT, SE is limited to explaining equivalent relations, whereas RFT postulates that equivalence relations may be one of many properties of relational frames.

**Properties of relational frames.** Relational frame theorists propose three properties of derived relations: mutual entailment, combinatorial entailment, and transformation of stimulus function (Barnes-Holmes et al., 2000; Dymond & Barnes, 1995). The first, mutual entailment, is a derived bidirectional stimulus relation based on the occurrence of two stimulus events (e.g. if A=B then B=A or A> B then B<A). that is, two or more mutually entailed relations results in additional derived relations. An example of this would be if it is trained that a mug weighs more than a feather, the student can derive that a feather weighs less than a mug in the absence of direct training. Moreover, combinatorial entailment relations are considered two or more trained relations results in the emergence of a third untrained relation (e.g. A>B and B>C, then A>C and C<A). If it is trained that a necklace costs more than a book, which also is taught to cost more than a pack of gum, one can derive that a necklace costs more than a pack of gum, based on the prior trained relations. The last derived relation is transformation of stimulus functions, which occurs when a psychological function attached to a particular stimulus transfer to another stimulus with that frame in the absence of training (Dymond & Rehfeldt, 2000). Dymond and Rehfeldt (2000) propose that training to stop at a stop sign and to stop walking when a crossing guard gestures to stop will result in a halt of behaviors in the classroom when a teacher says “stop”. Regarding educational significance, RFT suggests that learned operants can be acquired
derivationally, or in the absence of direct teaching across stimuli that are not related, as SE requires. Relational frame theorists suggest that derived relational responding emerges as a function of Multiple Exemplar Instruction (MEI; Hayes et al., 2001).

**Families of relational frames.** Hayes et al. (2001) defined relational frames as:

“a specific class of arbitrarily applicable relational responding that shows the contextually controlled qualities of mutual entailment, combinatorial mutual entailment, and transformation of stimulus functions; is due to a history of relational responding relevant to the contextual cues involved; and is not solely based on direct non-relational training with regard to the particular stimuli of interest, nor solely to nonarbitrary characteristics of either the stimuli or the relation between them.” (p. 33).

Within each of the aforementioned properties, there are types of relational frames. Common families of relational frames include coordination, opposition, distinction, comparison, hierarchical relations, temporal relations, and spatial relations.

Frames of coordination refer to the most fundamental relational response, one that encompasses equivalence, or sameness (e.g. Stimulus A is the same as Stimulus B). BiN, or the phenomenon of relating the name of an object (e.g. Stimulus A) to the visual representation of the object (Stimulus B), is an example of a frame of coordination. Theorists propose frames of coordination emerge prior to other relations because equivalent relations represent much of the early language training received by children (Hayes et al., 2001). Frames of opposition are organized around a specific dimension of a stimulus which differ in opposite directions, given a point of reference. For example, given the continuum of temperature, cold is the opposite of hot. Due to the imbedded frame of coordination in frames of opposition, such frames emerge following frames of coordination. Frames of distinction involve “responding to one event in
terms of its differences from another” (Hayes et al., 2001, p. 36); however, unlike frames of opposition, the nature of the response is not specified. If one was told, “this is not warm water”, there is no specification as to whether the water is cold or boiling. Frames of comparison define relations in which one event is to another event using qualitative/quantitative relation along a specified dimension. This family included subtypes such as bigger/smaller, faster/slower, and better/worse. Hierarchical relations define a similar basic pattern of frames of comparison; however, because it is not solely qualitative, the relation may be more specific without quantification. Similarly, temporal relations share basic patterns of comparative frames; however, because the primary measure of time is change, this family of relations is inherently more abstract (Hayes et al., 2001). Spatial relations define arrangement of one stimulus with regard to another stimulus, such as in-out, front-back, and under-over. Additional families of relations include conditionality and causality and deictic relations (Hayes et al., 2001).

**Verbal Behavior Developmental Theory (VBDT)**

Skinner’s *Verbal Behavior* (1957) may have been his most important work as evidenced by decades of research devoted to extending the theory of verbal behavior development (VBDT) following its publication (Greer, 2008; Greer & Ross, 2008; Greer & Speckman, 2009; Du & Greer, 2014). From Skinner’s *Verbal Behavior*, VBDT research seeks to identify the role of the environment in the development of verbal behavior developmental cusps and capabilities (Greer, 2008; Greer & Ross, 2008; Keohane & Greer, 2006).

Their early work suggested the pre-verbal foundational cusps function as the prerequisite for initially independent listener and speaker cusps/capabilities, which then join as one acquires higher order cusps/capabilities (Woolslayer, 2013). Rosales-Ruiz and Baer (1997) introduced behavioral developmental cusps as repertoires which enable one to learn new operants as a
function of contacting new contingencies in their environment. The establishment of a cusp results in accelerated learning and the establishment of novel stimulus control, specifically conditioned reinforcers for observing responses and sources of reinforcement for correspondence (Greer & Du, 2015; Greer & Keohane, 2006; Greer, Pistoljevic, Cahill, & Du, 2011; Greer & Ross, 2008; Greer & Speckman, 2009).

Early literature from verbal behavior developmental theorists discussed an evidence-based update to Skinner’s theory of verbal behavior in which they propose the developmental sequence of how initially independent listener and speaker repertoires join within one’s skin as prerequisites for higher order repertoires, as the basis of Verbal Behavior Developmental Theory (VBDT; Greer & Speckman, 2009). Verbal behavior development refers to experientially acquired capabilities to acquire novel operants and new relations, learn at a faster rate, and learn in new ways. Decades of research suggest that preverbal foundational repertoires serve as the prerequisite for the emergence of independent listener and speaker repertoires. When the listener and speaker repertoires join, evidence suggests that experiences occasion the intercept. Specifically, the joint attention condition under which a child matches the correct visual stimulus while simultaneously experiencing the auditory stimulus (tact for the stimulus) sets the occasion for listener and speaker repertoires to join, resulting in the emergence of the capability of BiN. The evidence of the identification and induction of missing verbal behavior developmental cusps and capabilities, such as BiN, through evidence-based intervention offer a developmental sequence of these verbal behavior developmental cusps and capabilities. Of note, is the educational implication of higher order cusps/capabilities, or complex academic repertoires.

Reports on the sequence of these repertoires arose from a decade of basic and applied research which sought identify the source of reinforcement for verbal behavior developmental
cusps and the behavior interventions, or protocols, to induce them (Greer & Longano, 2010; Greer & Ross, 2008; Greer & Speckman, 2009). Verbal behavior developmental research identified critical social reinforcers as well as learning cusps that induce functional language (Greer & Du, 2015). Skinner’s *Verbal Behavior* suggested that incorporating listener behavior was necessary for a more comprehensive analysis of verbal behavior, suggesting the interaction of listener and speaker (Skinner, 1957). In defining verbal behavior as social behavior, there must be study of the interlocking verbal operant between individuals, or verbal episodes (Skinner, 1957; Yoon, 2019). The onset of verbal behavior developmental cusps is identified through increased rate of learning, new reinforcers, and accessing novel contingencies. It appears that instructional histories which lead to development of complex repertoires source from reinforcement learning or conditioning histories, which emerge at the onset of the cusp (Greer & Du, 2015). Research on verbal episodes suggests the emergence of speaker-as-own-listener cusps, or verbal episodes beneath the skin, or self-talk (Farrell, 2017; Greer, Pohl, Du, & Moschella, 2017; Lodhi & Greer, 1989). Emergence of higher order cusps and capabilities, such as initially independent listener and speaker repertoires and the integration of listener and speaker repertoires are dependent upon the establishment of conditioned reinforcers, specifically social reinforcers.

**Pre-verbal foundational cusps.** Pre-verbal foundational cusps serve as the prerequisite repertoires for which complex verbal behavior emerge. These cusps are typically acquired in utero or early in infancy (Donahoe & Palmer, 1994), but often do not emerge for children with developmental delays (Greer et al., 2017). The pre-verbal foundational cusps and cusps that are capabilities include conditioned reinforcement for observing adult faces (Maffei, Singer-Dudek, & Keohane, 2014) and voices (Greer et al., 2011), conditioned reinforcement for observing
2D/3D stimuli and generalized match-to-sample (Du, Broto, & Greer, 2015), generalized imitation (Du & Greer, 2014), and “capacity for sameness” across the senses (Frias, 2017). The emergence of each cusps is defined by one’s observing and attending to a variety of new stimuli within their environment, that did not select out their attention before. That is, once one acquires conditioned reinforcement for orienting towards adult voices (Greer et al., 2011), they may begin to respond when their name is called or emit echoic responses.

**Listener cusps.** Once pre-verbal foundational cusps emerge, most children begin to encounter reinforcement for responding as a listener to novel stimuli within their environment. The establishment of listener cusps serves as a prerequisite for the acquisition of speaker cusps and eventually joining of listener and speaker (Greer & Speckman, 2009). Two listener cusps are listener literacy (Greer et al., 2005), in which one reliably responds to spoken instruction as a listener, and auditory matching (Choi, Greer, & Keohane, 2015), defined as the discrimination between speech-sound patterns. Following the onset of these cusps, one now has the “capacity to be governed by spoken consonant-vowel combinations (words, phonemes, and morphemes) emitted by a speaker” (Greer & Ross, 2008. p. 93). Such repertoires lead to the emergence of echoic behavior, a prerequisite for fluent speaker repertoires. Further, the onset of listener cusps serves as a prerequisite for acquisition of incidental listener responses.

**Speaker cusps.** The acquisition of pre-verbal foundational and listener cusps lead to the onset of speaker cusps. Despite this sequence, speaker repertoires emerge initially independent of listener repertoires (Greer & Speckman, 2009; Skinner, 1957). Speaker response are primarily maintained by accessing items/information/events from a listener (e.g. “I want a chip please” or “what time is it?”) or social reinforcement (e.g. “look, it’s a mail truck!”). Speaker cusps include parroting, echoic-to-mand, echoic-to-tact, all of which require attending to a vocal antecedent
and vocally responding (Greer & Ross, 2008). Parroting involves the production of a vocal antecedent in the absence of a mand or tact function (Yoon & Bennett, 2000). Echoic-to-mand involves repeating a vocal antecedent in order to access a specified reinforcer (e.g. requiring one to echo “gummy” when they want a gummy). Similarly, echoic-to-tact requires one to repeat a vocal antecedent which result in social reinforcers. These cusps are prerequisites to independent mands and tacts and serve as the building blocks for which listener and speaker repertoires integrate resulting in a truly verbal individual (Greer et al., 2017).

**Joining of listener and speaker.** At this point in the verbal developmental trajectory, an individual can acquire novel speaker and listener repertoires via direct training; however, the joining of the two repertoires leads to acquisition of both listener and speaker repertoires within one’s own skin (Greer & Speckman, 2009). Cusps within this domain include say-do correspondence, or reliable demonstration of acting as a listener to one’s own verbal behavior, self-talk, which involves rotating between listener and speaker roles within one’s own skin (Farrell, 2017) and BiN, which includes acquisition of incidental bidirectional operants (Frank, 2018). As one of the speaker-as-own-listener cusps, BiN is characterized as the joint stimulus control from listener to speaker functions such that experiencing a listener response occasions the tact response (Greer et al., 2005).

Empirical findings on BiN suggest that untaught listener repertoires emerge prior to the joining of listener and speaker responses, or bidirectional operants (Frank, 2018; Kleinert, 2018; Morgan, 2018; Greer & Speckman, 2009; Greer & Du, 2015; Greer et al., 2005; Greer & Longano, 2010; Miguel, 2016). According to Skinner (1957), listener and speaker responses to stimuli are initially independent and as one’s verbal community complexes, the listener and speaker responses join (Greer et al., 2005; Greer & Speckman, 2009). Not until the integration of
listener and speaker responses within the same skin can an individual be considered fully verbal (Barnes-Holmes et al., 2001; Greer et al., 2017; Greer & Longano, 2010; Greer & Ross, 2008; Greer & Speckman, 2009).

**Bidirectional verbal operants between people.** Skinner (1957) defined verbal behavior as behavior reinforced by the mediation of other people. That is, verbal behavior is social behavior. It is defined by interlocking contingencies between a listener and a speaker maintained by a history of reinforcement or punishment under similar contingencies such that the speaker and listener reinforce each other within a verbal episode (Skinner, 1957; Greer et al. 2017). Early literature on bidirectional operants between people defined such verbal episodes as conversational units, characterized by the social function associated with the rotating roles between a speaker and a listener (Donley & Greer, 1993; Lodhi & Greer, 1989). Recent literature suggested conversational units are a strong measure of social reinforcement (Greer et al., 2017; Greer & Du, 2015; Greer & Speckman, 2009).

Empirical evidence using group descriptive analyses across preschool-aged student’s interactions with mothers and peers suggest the role of bidirectional operants between caregivers and peers (Briggs-Greer, 2018; Yoon, 2019). Briggs-Greer (2018) analyzed conversational units between mother and child across 35 preschool-aged children with and without developmental disabilities. In reviewing mother-child interactions, she categorized the following responses (a) verbal operants, defined as mands, tacts, and intraverbals, (b) non-lexical verbal behavior, defined as grunts or whines, and (c) non-vocal verbal behavior, defined as gestures. She found no significant differences between the numbers of conversational units emitted by children of varying levels of verbal behavior, suggesting the reinforcement value for bidirectional operants between people.
Yoon (2019) added to the literature by finding a relationship between bidirectional operants and social reinforcers. She defined three bidirectional operants including verbal operants between people, bidirectional self-talk conversational units, and BiN. Such findings suggest the role of social reinforcement in acquisition of higher-order verbal development cusps/capabilities.

**Unidirectional and Bidirectional Naming**

BiN, or the emergence of word-object relations without direct training, is a behavioral phenomenon agreed upon across theories of language acquisition (Barnes-Holmes et al., 2000; Greer & Longano, 2010, 2015; Greer & Ross, 2008; Greer & Speckman, 2009; Hayes et al., 2001; Horne & Lowe, 1996; Miguel, 2016). Horne & Lowe (1996) initially proposed the naming theory and defined naming as a basic behavioral unit, the onset of which results in untaught higher order bidirectional relations. Horne and Lowe suggested that the emergence of naming resulted in the following, 1) emergent categorization of stimuli and 2) incidental emergence of listener and speaker responses, which is the foci of the studies herein. Once naming emerges, children can experience a word-object relation as a listener (e.g. mother says “here is your car”) while simultaneously observing the stimulus (e.g. a toy car) and without any direct training, emit the response under the same conditions as a listener (“point to car”) and as a speaker (e.g. “car”).

**BiN as a Verbal Behavior Cusp/Capability**

According to verbal behavior developmental theory (VBDT), the acquisition of BiN is a behavioral developmental cusp (Rosales-Ruiz & Baer, 1996), that is also a learning capability (Greer & Du, 2015; Greer & Longano, 2010; Greer & Speckman, 2009). VBD theorists consider BiN a cusp that is now a learning capability because once it is demonstrated, children learn new operants, as both a listener and speaker, in the absence of direct training. That is, following the
establishment of BiN, the child can learn under conditions in which they could not before its onset (Greer & Speckman, 2009).

**Common and Intraverbal BiN**

Hawkins, Gautreaux, and Chiesa (2018) suggested that Miguel’s (2016) proposed subtypes of naming can be further deconstructed to present BiN as a continuum. Miguel (2016) specifically discussed the subtypes of common BiN and intraverbal BiN. Common BiN can be defined as “the process of different stimuli evoking the same speaker and listener behavior and becoming members of the same class (Miguel, 2016, p. 130). In comparison, intraverbal BiN is defined by Miguel (2016) “as the establishment of stimuli as related or equivalent intraverbal relations” (Miguel, 2016, p. 134).

Hawkins et al. (2018) proposed that Miguel’s classification along with decades of empirical findings in the field of verbal behavior (Greer et al., 2005; Gilic & Greer, 2011; Longano & Greer, 2015) suggest a larger classification framework of the BiN continuum (Frank, 2018). Their dissection of empirical research yields six subtypes of naming including (1) listener unidirectional naming, (2) speaker unidirectional naming, (3) joint bidirectional naming (4) listener incidental unidirectional naming, (5) speaker incidental unidirectional naming, and (6) joint incidental bidirectional naming. These subcomponents offer a more detailed classification of individual’s degree of BiN as they acquire the more complex repertoires. Such classifications offer implications on skill acquisition, curriculum design, and continued contributions to existing research on BiN and related implications.

**BiN as a Dependent Variable**

Numerous studies on BiN have identified evidence-based interventions which function to condition reinforcers identified as prerequisites for the emergence of BiN (Greer et al., 2005;
Interventions which function to provide the necessary instructional histories for joint stimulus control to emerge across listener and speaker responses include Multiple Exemplar Instruction (MEI; Greer et al., 2005), Intensive Tact Instruction (ITI; Schaufler & Greer, 2006), and establishment of conditioned reinforcement for auditory and/or visual stimuli (Lo, 2016; Longano & Greer, 2015; Kleinert, 2016).

**Multiple Exemplar Instruction**

A commonly used intervention to induce BiN is Multiple Exemplar Instruction (MEI) across listener (match/point to) and speaker (tact/intraverbal tact) for novel stimuli (Greer et al., 2005; Nuzzolo-Gomez & Greer, 2004). MEI involves the rotation of directly trained listener and speaker responses (match, point to, tact, and intraverbal responses) as well as multiple exemplars of the target stimuli across irrelevant features (shape, size, etc.) to mastery. Greer, Chavez-Brown, Nirgudkar, Stolfi, and Rivera-Valdes (2003a) found that untaught novel responses across spoken and written spelling topographies emerged as a function of MEI for spelling words. Similarly, Nuzzolo-Gomez and Greer (2004) implemented MEI to induce joint establishing operation control across mand and tact functions. In the seminal study on BiN, Greer et al. (2005) used MEI as the intervention to establish joint stimulus control for listener and speaker responses, which was not present prior to the MEI experiences. As such, MEI is an effective intervention to join listener and speaker responses (Greer et al., 2005; Gilic & Greer, 2011; Fiorile & Greer, 2007). It appears the instructional history of rotating listener and speaker responses functions to fuse the two repertoires, emerging in joint stimulus control across listener and speaker responses, resulting in the emergence of BiN (Greer et al., 2005).

**Intensive Tact Instruction**
Another intervention which sets the occasion for BiN to emerge in the verbal behavior literature is Intensive Tact Instruction (ITI), in which an individual is immersed in opportunities to encounter reinforcement for novel tacts (Delgado & Oblak, 2007; Greer & Du, 2010; Schauffler & Greer, 2006; Pistoljevic & Greer, 2008). Expansive tact repertoires appear critical in the acquisition of complex verbal developmental cusps/capabilities (Greer & Du, 2010). ITI (Schauffler & Greer, 2006; Pistoljevic & Greer, 2008; Delgado & Oblak, 2007; Greer & Du, 2010), which includes adding 100 additional learn units of tact instruction to a child’s instruction, functions to provide an instructional history for speaker responses resulting in the joining of listener and speaker responses. In addition to setting the occasion for the joint stimulus control of listener and speaker responses, research on ITI has shown increased vocal operants during free play, specifically increased tacts (Pistoljevic & Greer, 2008; Schauffler & Greer, 2006). Pistoljevic and Greer (2008) expanded on such findings by suggesting that not only did vocal operants increased post-ITI, but participants demonstrated the emergence of BiN as a function of the intervention.

**Conditioned Reinforcement for Visual/Auditory Stimuli.**

To investigate the sources of reinforcement responsible for the onset of BiN, Longano & Greer (2015) examined the effects of conditioned reinforcement for observing visual and auditory stimuli on the establishment of incidental listener and speaker responses. During intervention, either visual or auditory stimuli were conditioned as reinforcers using stimulus-stimulus pairing procedures until both visual and auditory stimuli acquired reinforcing properties. This was defined by the stimuli selecting out the observing response of the participants. Following the intervention, participants acquired the names of stimuli used during pre-intervention training as well as the name of novel stimuli. Such results suggest the source of
reinforcement for BiN to be observing responses for auditory and visual stimuli. Additional procedures which function to induce joint stimulus control for listener and speaker responses include repeated naming experiences (Kleinert, 2018; Lo, 2016), echoic training (Cao & Greer, 2019), and naming experiences with actions (Cahill & Greer, 2014).

**Naming Experiences**

When assessing for BiN, experimenters simulate naturalistic experiences for which novel visual stimuli (e.g. objects) are paired with the auditory stimuli (e.g. word), to provide opportunities for an individual to experience word-object relations. Two procedures to provide naming experiences to participants include match-to-sample (MTS) experiences (Greer et al., 2005; Longano & Greer, 2015) and tact experiences (Kleinert, 2018). A third attempted approach for students under 36-months-old include a storybook experience. Regardless of experience, the test of joint stimulus control is conducted two-hours following experiences (Frank, 2018; Greer et al., 2005; Kleinert, 2018; Lo, 2016).

**Match-to-Sample (MTS) Experience.**

To provide opportunities for an individual to observe novel stimuli while simultaneously encounter the auditory stimulus, experimenters utilize a MTS experience (Frank, 2018; Greer et al., 2005; Hranchuk et al., 2018; Fiorile & Greer, 2007), using learn unit (Albers & Greer, 1991) instruction. During such experiences, participants are provided with a field of three stimuli, one target and two non-targets, and a fourth stimuli (identical match to the target stimulus) along with vocal antecedent of “match _____”, for five novel stimuli. Correct visual matches result in reinforcement and incorrect responses result in the correct procedure (Longano & Greer, 2015). Match instruction is continued until participants respond with 90% visual matching accuracy across two consecutive sessions for 20 learn units.
Incidental Naming Experience

Incidental naming experiences consist of repeated pairings of visual and auditory stimuli (i.e. word-object relations; Kleinert, 2018). That is, experimenters provide participants with opportunities to incidentally observe the novel visual stimulus simultaneous with the experimenter saying the name of the novel stimulus. Similar to MTS, sets of stimuli typically include 5 novel stimuli, presented four times, for a total of 20 experiences. Sequence of such experiences include: (1) presentation of target visual stimulus, (2) experimenter gaining attention of participant towards the visual, (3) experimenter provides auditory stimulus. Compared to the MTS experience, experiments present a single session of experiences with a specific set of stimuli (Hranchuk, Longano, & Greer, 2018; Kleinert, 2016).

Storybook Naming Experience

Practitioners assessing for the presence of BiN in toddler-aged students have developed a storybook naming experience as an attempted approach to contrive environmental experiences most similar to a parent-child interaction (Farrell, Romas, Speckman, Chen, & Greer, 2018). The storybook naming experience consists of the experimenter reading a story to the child in which the target stimuli are embedded into a story plot (e.g. “The cow went to the farm”). The assessment for presence of BiN is completed across listener and speaker responses using procedures similar to the aforementioned studies. Farrell et al. (2018) conducted an analysis of archival data across four years in which they identified correlates of BiN using the storybook naming experience. They found that age is correlated with onset of BiN (Gilic & Greer, 2011) and further validated findings that UniN emerges prior to the joining of listener and speaker (Frank, 2018). They also found that repeated naming experiences have significant main effects
on onset of UniN and BiN, further validating findings of Kleinert (2018). Experiment I was originated as an extension of these findings.

**Sources of Reinforcement**

While the various behavior analytic accounts of emergent behaviors agree that BiN plays an integral role in incidental language learning, they vary in their explanation of the sources of reinforcement responsible for its onset (Longano & Greer, 2015; Hayes et al., 2001; Horne & Lowe, 1996)

**Naming Loop**

Horne and Lowe (1996) proposed the *naming loop* as the source of reinforcement for naming. The initial link of the loop is the child’s listener response (e.g. orienting towards a stimulus) as the caregiver delivers the tact for the stimulus (e.g. “car”). The child may also emit an echoic response which may be reinforced by the caregiver. The final link of the loop is the child’s emission of the tact. Reinforcement from the caregiver sustains the listener responses until the echoic response acquires reinforcing properties to sustain the child’s own listener response, defining the loop. Horne and Lowe (1996) suggested the source of reinforcement responsible for the emergence of BiN to be overt, and eventually covert, echoics. Findings of Lowenkron and colleagues (1991) add a simulated echoics as the source of reinforcement in their research on signed tacts and the role of echoic rehearsal in the emergence of untrained listener and speaker responses.

**Observing Responses**

VBDT (Greer & Ross, 2008; Greer & Speckman, 2009; Greer & Longano, 2010) focus on identifying the source of reinforcement for BiN. VBD theorists agree with Horne & Lowe (1996) in the integral role of the echoic in the fusing of listener and speaker responses, however,
suggest that the initial source of reinforcement for incidental listener and speaker responses is the observing response. Greer & Longano (2010) and Longano & Greer (2015) suggest that the source of the reinforcement for BiN is multiply controlled reinforcers for observing responses. That is, the listener and speaker responses could not join until the child demonstrated conditioned reinforcement for observing auditory and visual stimuli (Longano & Greer, 2015).

Greer et al. (2011) suggest that automatic reinforcement for speech sound production, or conditioned reinforcement for observing voices plays a vital role in the emergence of BiN as well. According to VBDT, BiN is not only a verbal developmental cusp (Rosales-Ruiz & Baer, 1996), but it is a cusp that is also a capability (Greer & Speckman, 2009). Following the establishment of a verbal developmental cusp one can access new contingencies in their environment; however, the establishment of a capability is defined when one can learn in new ways (Greer & Speckman, 2009). BiN is considered a cusp that is also a capability because one it emerges the child can access direct contingencies in one mode of instruction (e.g. listener response) and emit the same response in the opposite mode (e.g. speaker response), or vice versa, thus explaining the bi-directionality of this capability.

Implications of BiN

**BiN as an Independent Variable**

The presence or absence of BiN has educational implications in how the child can learn and thus instructional practices can be adjusted to reflect the newly acquired repertoires. BiN is a necessary cusp for a general education classroom to maximize efficient instruction, according to VBDT (Greer & Ross, 2008; Greer & Speckman, 2009). VBD theorists have demonstrated that once BiN is present, a child can learn through instructional demonstrations, whereas prior to the joining of listener and speaker responses, a child cannot learn through such instructional
practices (Greer et al., 2011; Hranchuk et al., 2018). If BiN is not present in one’s repertoire, they are not likely to learn from instructional practices which are typically implemented in general education classrooms (Greer et al., 2011). Findings of these studies suggest that instructional practices should be adjusted following the emergence of BiN to increase opportunities to respond to learn unit instruction (Albers & Greer, 1991; Greer, Corwin, & Buttigieg, 2011; Hranchuk et al., 2018). Hranchuk et al. (2018) demonstrated that following the presentation of Instructional Demonstration Learn Units (IDLUs), students with BiN required fewer learn units to master novel repertoires.

**BiN as a Prerequisite**

Further, children who demonstrate the presence of BiN can acquire more complex repertoires and verbal development cusps and capabilities such as observation learning (Greer et al., 2006) as well as naming joins print stimulus control (Lee-Park, 2005; Helou-Care, 2008). In a series of studies, Helou-Care (2018) suggested that for some middle-school students with developmental delays, the absence of BiN may have been functionally related to reading comprehension difficulties. Results of a second study suggested that the establishment of BiN, resulted in significant increases in reading comprehension accuracy. More recently Bly (2019) and Gentilini (2019) further demonstrated that following the establishment of conditioned reinforcement for observing book stimuli, measures of vocabulary increased, suggesting the role of BiN for word-object relations in acquisition of higher-order cusps/capabilities.

**Conditioning Procedures and Order of Stimulus Presentation**

Behavioral perspectives on acquisition of novel repertoires distinguish between two categories of conditioning: respondent and operant (Pear & Eldridge, 1984). Catania (1968) defined respondent conditioning as modification of behavior by pairing it with another stimulus
and operant conditioning as modification of behavior as a result of its consequences. While both result in neutral stimuli acquiring reinforcing properties, they differ in the temporal relationship between a conditioning stimulus and unconditioned stimulus. With regard to the emergence of BiN, when providing experiences for novel auditory and visual stimuli, experimenters typically present target auditory and visual stimuli simultaneously (Frank, 2018; Gilic & Greer, 2011; Greer et al., 2005; Longano & Greer, 2015; Kleinert, 2018). However, researchers have manipulated the order of stimulus presentation to test such effects on the acquisition of novel repertoires (Petursdottir & Aguilar, 2016).

**Respondent Behavior**

Respondent behavior is behavior elicited by antecedent stimuli (Cooper, Heron, & Heward, 2007; Donahoe & Palmer, 2004) and is the response component of a stimulus-response reflex. Respondents are recruited by specific antecedent stimuli and can be elicited by conditioned or unconditioned stimuli (Buttigieg, 2015; Greer & Ross, 2008). Pavlovian conditioned, also known as classical conditioning, is the procedure in which conditioned and unconditioned stimuli are presented simultaneously, referred to in the verbal behavior literature as stimulus-stimulus pairing (Greer & Ross, 2008).

Stimulus-stimulus pairing procedures are characterized by simultaneous presentation of neutral and conditioned stimuli (Sundberg, Michael, Partington, & Sundberg, 1996). That is, during pairing, conditioned reinforcers (e.g. praise) is paired with neutral stimuli (e.g. puzzles) until the neutral stimulus acquires reinforcing properties. In verbal behavior literature, researchers have effectively utilized stimulus-stimulus pairing procedures to replace aberrant behaviors with new conditioned reinforcers (Greer, Saxe, Becker, & Mirabella, 1985; Nuzzolo-Gomez, Leonard, Ortiz, Rivera, & Greer, 2002). The implementation of teaching operations,
such as a pairing procedure, teach a student to independently seek out appropriate manipulation of stimuli in their environment rather than emitting behaviors with no external consequences, such as stereotypy and passivity (Greer, 2002). Conditioning appropriate stimuli as reinforcers acts to displace the automatic reinforcement delivered through emission of stereotypy and passivity for many children and can result in accelerated rates of learning (Greer et al., 1985; Greer et al., 2011; Nuzzolo-Gomez, et al., 2002; Tsai & Greer, 2006).

With regard to transformation of stimulus function from listener to speaker, Longano and Greer (2015) implemented stimulus pairing procedures to condition either visual or auditory stimuli, resulting in the onset of novel word-object relations. During intervention, either visual or auditory stimuli were conditioned as reinforcers using stimulus-stimulus pairing procedures until both visual and auditory stimuli acquired reinforcing properties. Following the intervention, participants acquired the names of stimuli used during pre-intervention training as well as the name of novel stimuli. Such results suggest the source of reinforcement for BiN to be conditioned reinforcement for observing auditory and visual stimuli.

**Operant Behavior**

Operant behaviors are selected out by their consequences (Cooper et al., 2007; Greer & Ross, 2008) and emerge as a function of reinforcement or punishment occurring after the emission of the target behavior. The future frequency of operant behavior is determined as a function of the history of consequence. While respondent behavior is elicited by antecedent stimuli, operant behavior is maintained by stimuli that post cede it, known as selection by consequence. VBDT focuses on operant behavior in acquisition of novel repertoires, using the learn unit (Albers & Greer, 1991). That is, learning, is defined as “the acquisition of operants or
higher order operants as a function of direct contact with contingencies of reinforcement or punishment” (Greer et al., 2006, p. 489).

With regards to verbal behavior, Skinner (1957) discussed classes of operants based on their function. That is, the response operates on the environment to result in a change in environment-behavior relations, defined by the emergence of removal of some stimulus (Donahoe & Palmer, 2004). Greer and Han (2015) suggest that both classical and operant conditioning procedures can establish conditioned reinforcers. With regard to incidental language acquisition, most research on BiN contrive environmental conditions to simultaneously pair a novel visual stimulus with a novel auditory stimulus (word-object relations); however, research is warranted on the role of proximity in transformation of stimulus function from listener to speaker responses, or the establishment of BiN.

**Role of Proximity of Conditioned and Unconditioned Stimuli**

The temporal relationship between the conditioned stimulus (CS) and unconditioned stimulus (US) may affect the degree to which the unconditioned stimulus acquires reinforcing properties, known as *trace conditioning* (Bansgasser, Waxler, Santollo, & Shors, 2006; Pavlov, 1927). Trace conditioning consists of presentation of the CS, then following its termination, the US is presented. Temporal arrangements be delayed (CS presented and then US) or simultaneous (CS and US presented at the same time). While research on trace conditioning emerged from the neuroscience field and is focused on engagement of the hippocampus related to memory recall, it can be considered when analyzing the function of stimulus presentation for incidental word learning (Bansgasser et al., 2006). That is, to what extent does temporal contiguity of CS and US affect the degree to which an individual can acquire novel operants as a function of environmental experiences?
The phenomenon of temporal relations of stimuli has been tested across several species including rats and pigeons (Lattal & Gleeson, 1990) and fish (Lattal & Metzger, 1994). In considering delayed consequences for human participants, delayed consequence produces few, yet persistent rates of correct responding (Critchfield & Lattal, 1993; Lattal & Gleeson, 1990; Stromer, McComas, & Rehfeldt, 2000). Behavior analysts focus on the order of stimulus presentation as it relates to responding as a listener to receptive identification tasks (Petursdottir & Aguilar, 2016). Petursdottir and Aguilar (2016) compared acquisition of receptive identification tasks under two conditions: sample-first presentation and comparison-first presentation. Typically developing preschool-aged students reached mastery criterion in fewer trials during sample-first conditions that comparison-first conditions, which was replicated in a subsequent study (Schneider, Devine, Aguilar, & Petursdottir, 2018). Results are discussed with regards to the role of observing responses for sample stimuli. Given the sample stimulus before the comparison stimuli, participants were required to observe the sample stimulus first, which may have resulted in enhanced stimulus control for the sample stimulus and spoken word (Petursdottir & Aguilar, 2016). The aforementioned research offer implications towards acquisition of more complex conditional discriminations such as incidental language learning and other derived relations. The study included herein attempted to manipulate order of stimulus presentation with regard to incidental language acquisition.

**Incidental Language Learning as Derived Relations**

The onset of BiN is characterized by the joint stimulus control across listener and speaker responses, resulting in bidirectional operants (Frank, 2018; Lowenkron, 1991). Research findings examining the potential overlapping repertoires across theoretical accounts of incidental language learning (SE, RFT, and VBDT) demonstrate that acquisition of BiN functions as a
prerequisite for acquisition of more complex relations, including arbitrarily applicable relations (AAR; Frank, 2018; Morgan, 2018). Both RFT and VBDT discuss the emergence of bidirectional operants based on their function; however, RFT describes the onset of derived relations as generalized operants classes while VBDT describes that such repertoires emerge as a history of reinforcement for correspondence (Greer & Speckman, 2009).

**Verbal Behavior as Generalized Operant Classes**

Operant behavior, as reviewed above, is behavior selected out by consequences (Greer & Ross, 2008). While function remains constant (e.g. social reinforcement), its topography may vary greatly even consist of cross-modal behavior (e.g. spoken, gestural). Generalized operant classes are defined as a group of behavior, all of which produce the same effect on the environment (Barnes-Holmes & Barnes-Holmes, 2000; Catania, 1996). For example, greeting someone can have several responses including waving, saying “hello”, or smile, all of which result in the same consequence (e.g. greeting back). Catania (1996) proposed identity matching as an example of an operant class in that it can describe the consistent response of pairing two identical stimuli and function (e.g. reinforcement for correspondence between the two stimuli), yet identity matching can be emitted across a variety of stimuli (e.g. matching walnut, pen, or dog).

RF theorists propose an operant approach to explain the relational frame, as a unit of analysis is a three-term contingency consisting of (1) history of differential reinforcement, (2) relational response, and (3) contextual cue (Healy, Barnes-Holmes, & Smeets, 2000). VBDT research suggest that such generalized operant classes emerge as a history of correspondence (Greer & Speckman, 2009). During pre-verbal foundational stages of verbal development, one acquires generalized imitation, or *see-do correspondence* (Greer & Speckman, 2009) while
auditory matching, a listener cusp, consists of *hear-say correspondence*. The joining of listener and speaker repertoires, or bidirectional operants, can be classified as *see-say correspondence* and *say-do correspondence*. It appears that reinforcement for such correspondence provides the necessary prerequisites for such generalized operant classes to emerge and expand as a function of environmental experiences rather than as a result of direct training.

**Bidirectional Operants and Derived Relations**

The acquisition of BiN, the emergences of untrained word-object relations, is a bidirectional relation. Given BiN is also a learning capability, its onset provides the history of reinforcement necessary for one to learn in new ways. Recent research on BiN and its implications have focused on testing the effects of its onset and acquisition of other language relations, bridging the gap between behavior analytic accounts of word learning.

Morgan (2018) analyzed relations between degrees of BiN and the establishment of arbitrary and non-arbitrary relational responses. In Experiment I, she found that students who demonstrated BiN for unfamiliar stimuli (e.g. Chinese symbols) could derive complex relations (e.g. AAR). In a second experiment, she further demonstrated that simpler derived relations could emerge for individuals with UniN; however, complex derived relations (AAR) emerged if one demonstrated BiN. These findings suggest strong associations between acquisition of word-object relations and acquisition of other incidental language relations. This suggests BiN is a continuum with which stronger degrees of stimulus control may predict outcomes of other derived language relations. Similarly, Frank (2018) found that degrees of BiN may predict outcomes of basic concept knowledge as measured on the *Boehm Test of Basic Concepts 3rd Edition- Preschool Version* (BTBC3-P; Boehm, 2001). The onset of BiN has implications beyond how one can learn new repertoires to what one can acquire from environmental
experiences. Further research is warranted on the relation between contextually controlled relations and the establishment of BiN (Frank, 2018; Morgan, 2018), specifically, if the establishment of BiN functions to set the conditions for which AAR can be acquired.

**Outline and Rationale for the Current Study**

The purpose of the present study was to examine the relations among variables associated with measures of BiN for toddler-aged participants. In Experiment I, I evaluated the correlations between voluntary echoics during environmental experiences with novel stimuli (word-object relations) and the onset of BiN. In Experiment II, I further examined the storybook naming experience to test if a functional relation exists between echoic correspondence, or whether or not a child can produce a complete echoic, and the onset of BiN. I conducted Experiment III to test whether incidental naming experience is a more effective method for measuring BiN for toddler-aged students while also examining the role of proximity of visual and auditory stimuli on the emergence of BiN. Secondary findings of this study lead to further research questions addressed in Experiment III in which I examined where on the continuum of BiN can children acquire untrained language relations, replicated methods to those in Morgan (2018). This series of studies significantly add to the growing body of research on BiN and contribute to theoretical accounts of complex language relations.

**Rationale for Experiment I: Group Descriptive Analysis**

Given the decades of research on BiN, its educational implications, and the potential sources of reinforcement responsible for its onset, the purpose of the current study was to identify variables correlated with the degree of BiN, defined by the percentage of correct, untaught listener/speaker responses for toddlers aged 20- to 37-months-old. Based on the findings of literature reviewed above, I proposed that there would be significant positive correlations between
voluntary echoics during the experience and the percentage of correct, untaught speaker responses. Such relations would further validate the findings of previous studies (Cao & Greer, 2019; Longano & Greer, 2015) in demonstrating that increased voluntary echoics lead to increased speaker responses. Further, I hypothesized that following successive experiences and the emergence of unidirectional naming (UniN), the listener and speaker responses would join (Frank, 2018; Kleinert, 2018; Lo, 2016). The findings of Farrell et al (2018) warrant continued investigation into the correlates of variables considered during naming experiences to further validate the sources of reinforcement of BiN as suggested by Longano & Greer (2015). For toddler-aged participants, studies have suggested that BiN can emerge as early as two-years-old (Gilic & Greer, 2011). Attempted approaches to mirror caregiver-child interactions include a storybook naming experience in which the experimenter reads a story to the child with target stimuli embedded into the story. To date there are no previous studies evaluating the effects of such procedures.

**Research Questions for Experiment I**

1. What is the relation between the occasions of voluntarily saying the name of the target stimuli during a storybook experience and the percentage of correct, untaught listener and speaker responses for novel, familiar stimuli?

2. What is the relation between correct, untaught listener responses and correct, untaught speaker responses?

3. Are there significant differences in correct listener and speaker responses across the three experiences?
Chapter II

EXPERIMENT I: DESCRIPTIVE ANALYSIS OF UNTAUGHT LISTENER AND SPEAKER RESPONSES USING A STORYBOOK NAMING EXPERIENCE

Method

Participants

I selected participants from a CABAS® (Comprehensive Application of Applied Behavior Analysis to Schooling) accredited preschool located outside a metropolitan area in the Eastern United States. In this setting, applied behavior analytic practices were systematically implemented across all instruction. Their verbal repertoires were assessed using the CABAS International Curriculum and Inventory of Repertoires for Children from Preschool through Kindergarten (C-PIRK®; Greer, 2014). At the onset of the study, I selected the participants as they demonstrated relevant prerequisites for the establishment of BiN: conditioned reinforcement for observing voices, conditioned reinforcement for observing 2D stimuli, conditioned reinforcement for observing 3D stimuli, point topography, and independent mands and tacts. None of the participants had exposure to Storybook naming experiences prior to the study.

I recruited 22 monolingual, American English speaking toddlers and 2 bilingual (American English and Spanish) toddlers, with a mean age of 28.33 months at the onset of testing ($SD = 4.82$) (see Table 1), with and without disabilities. Among the 24 participants, 9 participants were female (37.50%) and 15 were males (62.50%). The mean age of female participants was 25.78 months and the mean age of the male participants was 29.87. Participants were recruited from an Early Intervention inclusion classroom within a preschool serving students with and without disabilities in a large, metropolitan area in the northeast. The sample consisted of 8 toddlers with neurotypical development (33.3%) and 16 toddlers with at risk for
developmental disabilities as classified by their Individualized Family Service Plan (IFSP; 66.70%). We confirmed the participant’s IFSP status by checking their student file with the school’s administrators. In order to access Early Intervention services from the county, the participants were required to have an IFSP.

Of the male participants, 12 (80%) had IFSPs and of the females, 4 (44%) had IFSPs. There was not a significant difference between sex and IFSP status ($\chi^2(1, N = 24) = 3.20, p = .074$). Although there was not a significant correlation between sex and IFSP status, the pattern of frequencies revealed a trend towards an association between male gender and IFSP status. Additionally, there was a significant difference in mean age of participants without IFSP (23.50 months) and participants with IFSPs (30.75 months), $t(22) = -4.937, p < .001$.

**Setting and Materials**

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**Table 1**

*Characteristics of the Participants for Experiment I*

<table>
<thead>
<tr>
<th></th>
<th>Age in Months (Years)</th>
<th>Sex</th>
<th>IFSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td>--</td>
<td>37.5</td>
<td>62.5</td>
</tr>
<tr>
<td>Mean months (year)</td>
<td>28.33 (2.39)</td>
<td>25.78</td>
<td>29.87</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>4.82 (.410)</td>
<td>4.35</td>
<td>4.53</td>
</tr>
<tr>
<td>Range</td>
<td>20.00-37.00 (1.58-3.13)</td>
<td>20.00-33.00</td>
<td>21.00-37.00</td>
</tr>
</tbody>
</table>
Experimenters collected data during regularly scheduled instructional periods of the school day in the participants’ classroom. Experimenters utilized a one-to-one method for probe sessions, with the exception of a second, independent observer, and intervention sessions were also conducted in one-on-one sessions while other children were in the classroom. The other participants could not see or hear the intervention sessions to eliminate potential confounding variables. I conducted one naming experience and probe per school day. Typically, I delivered the naming experience first thing in the morning to provide time for the naming probe, which required a two-hour delay. Conducting the experience first thing in the day also controlled for the potential of intervention sessions to interfere with daily activities (e.g. nap time).

Materials used during naming experience and subsequent probes included pre-constructed data sheets with the names of the stimuli and a printed storybook for which the participants observed 24 opportunities (six opportunities across four operants). Each book consisted of multiple exemplars that were systematically used for pre- and post-intervention sessions. The materials used for naming experiences sessions and subsequent probes included a bound book, *A Day at the Zoo* and *Melanie’s Garden* (see Appendix A). During the naming probe, we used pre-constructed data sheets with place to collect data on two opportunities to respond as a listener and speaker per target stimulus.

**Dependent Variables**

I measured the following dependent variables: number of occasions the participants voluntarily said the name of the target stimulus during the naming experience and the accuracy of listener and speaker responses.

**Voluntarily saying the name of the target stimulus.** I measured the number of occasions the participants voluntarily said the name of the target stimulus during the naming
experience. This was defined as (a) the emission of a response immediately following the response of the experimenter (e.g. echoic) or (b) the emission of a delayed response following the experimenter’s antecedent (e.g. delayed echoic), both of which held formal similarity and point-to-point correspondence with the target stimulus. Given that the experience was presented using a storybook, there were often temporal delays from experimenter’s presentation of the target auditory stimulus (“Koop”) and the participant’s opportunity to voluntarily emit a target stimulus (“e.g. “Koop”). We could not define all responses as echoics, since responses often were not proximate to the antecedent (e.g. “Koop ate a hamburger” with the target stimulus being “Koop”).

For the purposes of this study, we only collected data on the voluntary responses for the names of the target stimuli. An example of a target response was as follows: experimenter said, “Koop ate a hamburger” and the participant said “Koop”. I did not consider echoic responses for non-target words. An example of a non-target response was as follows: experimenter said, “Koop ate a hamburger” and the participant said “hamburger”. The participants were given a total number of 24 opportunities to emit an echoic response. Scores were reported as a total number of voluntary responses emitted for each session.

Listener responses. Two hours following the experience, I measured the number of listener (point to) responses the participants emitted. I gave the participants 2 opportunities to respond to the following antecedent, “Point to ____” for each target stimuli for a total of 8 listener responses. During each opportunity, I presented the participants with a sheet of paper which contained three pictures, the target stimuli and two additional pictures of stimuli from the current set of stimuli (non-exemplars). We delivered the antecedent, “Point to/Show me/Find ____” and allowed the participant 3 s to emit a response. No consequence was delivered
for correct or incorrect responses. Scores were reported as percentages. Criteria was considered 75% correct listener responses (6 out of 8 correct listener responses). If participants demonstrated 100% accuracy during the first opportunity, we did not present a second opportunity to label the stimuli (e.g. 4 out of 4 speaker responses).

**Speaker responses.** Following the listener response probe, I measured the number of speaker (intraverbal tact) responses the participants emitted. I gave the participants 2 opportunities to respond to label the target stimuli following the presentation of the stimuli. During each opportunity, I presented the participants with a picture of the target stimuli and the antecedent “Who is this?” or “This is ___”. I gave the participants 3 s to label the target stimuli. No consequence was delivered for correct or incorrect responses. Scores were reported as percentages. Criteria was considered 75% correct speaker responses (6 out of 8 correct speaker responses). If participants demonstrated 100% accuracy during the first opportunity, we did not present a second opportunity to label the stimuli (e.g. 4 out of 4 speaker responses).

**Independent Variable: Successive Naming Experiences with Identical Stimuli**

The independent variable of the study was successive naming experiences across identical familiar stimuli (SNEIS) using a storybook experience (Farrell et al., 2018). Each session consisted of a naming experience in which experimenters read a story giving the participant 24 opportunities to simultaneously view the visual stimuli while the experimenter labeled the name paired with the stimulus (e.g. “Hi Koop”). I presented the naming experience and subsequent naming probes for three consecutive days using the same book, stimuli, and procedures. Each session consisted of 1) a naming experience and 2) a subsequent naming probe (two-hours following the experience). That is, two-hours following a naming experience we conducted listener (selection) and speaker (tact) probes. The listener probes consisted of two
opportunities to select the four target stimuli from a field of three (e.g. “point to Kaper”). The speaker probes consisted of two opportunities to label the four target stimuli in a field of one (e.g. picture of Kaper). We measured the effects of consecutive exposures to naming experiences on the participants’ voluntarily saying the name of the target stimulus and the accuracy of listener and speaker responses.

Data Collection

During the experience and subsequent probe, I recorded data using a pen and pre-made data sheet. I reported a correct or target response with a plus (+) and an incorrect or nontarget response with a minus (-). I recorded voluntarily saying the name of the target stimulus as a total number of responses and recorded listener and speaker responses as percentages. I used IBM Statistical Package for the Social Sciences (SPSS®) to conduct all statistical tests.

Design

I used a group descriptive analysis to test the effects of consecutive naming experiences using a storybook on accuracy of listener/speaker responses. The purpose of this design was to determine relations between storybook naming experiences, specifically the participants voluntarily saying the name of the target stimuli, and the accuracy of listener/speaker responses. I did not experimentally control or manipulate the variables tested in this study. Potential covariates of the study included age, gender, and student classification and I conducted preliminary analysis to rule out potential covariates (see Tables 2 and 3).

Procedures

I collected data during the participant’s school day, typically across three consecutive school days. Data collection occurred during regularly scheduled instructional times. Each session consisted of a naming experience and subsequent naming probe, which was conducted
two hours following the experience. Given the time delay requirement, I presented the naming experience first thing following arrival to school. This allowed for the two-hour delay prior to the probe, given the schedule for Early Intervention was 2.5 hours for some of the participants.

During the experience, the experimenter and participant sat at a child-sized table both oriented towards the stimuli. The experimenter used a storybook which contained pictures of the target stimuli set up in a typical, storybook fashion. The experimenter presented the target stimuli, 3-4 stimuli made up a storybook, by pointing to the picture while simultaneously label the character’s name (“This is Koop”). I presented each stimulus 6 times, for a minimum of 24 opportunities to observe the stimuli and hear the name. I provided additional opportunities contingent on the participant not observing the stimulus, defined as the participant shifting gaze away from the target stimulus. During the experience, the experimenter collected data on whether or not the participant voluntarily said the names of the target stimuli (e.g. experimenter said, “This is Koop” and participant responded “Koop”).

Two-hours following a naming experience for a set of stimuli (see Figure 1), I conducted listener and speaker probes. The listener probes consisted of two opportunities to select the four target stimuli from a field of three (e.g. “point to Kaper”). During the listener probe trials, the experimenter gained the attention of the participant and presented three visuals from the storybook (e.g. one target exemplar and two non-exemplars) along with the vocal antecedent, “point to __”. I delivered 2 opportunities to point to all of the target stimuli for a total of 8 opportunities. Following 8 opportunities to respond as a listener, I presented the speaker probes. The speaker probes consisted of two opportunities to label the four target stimuli in a field of one (e.g. “Kaper”), for a total of 8 opportunities.

**Interobserver Agreement (IOA)**
Across probe and intervention sessions, I collected data on the percentage of interobserver agreement (IOA) using a second, independent observer. I used the Teacher Performance, Rate and Accuracy (TPRA; Ingham & Greer, 1992) to ensure procedural integrity during naming experiences and subsequent probes. I calculated IOA by dividing the total number of correct responses recorded by one observer (the lower of the two totals) by the total number of correct responses recorded by the other observer and multiplying the result by 100 percent. I report interobserver agreement for probe sessions which consisted of listener and speaker responses as one session. We collected IOA for 30% of naming experiences and 35% of probe sessions with 100% agreement across listener and speaker responses.

Results

Preliminary Analyses

In examining the variables associated with the emergence of BiN, we tested for differences in demographics, such as sex and IFSP status (see Tables 2 and 3). A Chi Square test showed there was a marginal difference between sex and IFSP status, $\chi^2(1, N = 24) = 3.20, p = .074$. An independent samples $t$ test showed there was a significant difference between the ages of participants without IFSPs and without IFSPs, $t(22) = -4.937, p < .001$.

Age and listener/speaker responses. A Pearson correlation revealed there was no significant correlation between age (in months) and percentage of correct listener responses across Experience 1, $r(22) = -.053, p = .807$, Experience 2, $r(22) = .196, p = .358$, and $r(22) = .308, p = .143$ or Experience 3. Age (in months) and percentage of correct speaker responses were not correlated across Experience 1, $r(22) = .061, p = .777$, Experience 2, $r(22) = .250, p = .238$, and Experience 3, $r(22) = .316, p = .133$.

IFSP status and listener/speaker responses. To analyze group differences between
IFSP status and typically developing students and the percentage of correct listener and speaker responses, we used an independent samples $t$ test. There were no significant differences in listener and speaker responses across IFSP status (see Table 2).

**Sex and listener/speaker responses.** To analyze group differences between sex and the percentage of correct listener and speaker responses, we used an independent samples $t$ test. There was a significant difference between the percentage of correct, untaught speaker responses for the second experience between females and males, $t (21.63) = -.536, p = .004$. The percentage of correct speaker were significantly higher for males ($M = 21.67$) than females ($M = 16.67$). There were no other significant group differences (see Table 3). Given the results of the preliminary analysis, age, sex, and IFSP status were excluded as covariates in continued analysis.

**Voluntarily Saying the Name of the Target Stimulus**

There was a significant positive correlation between the number of occasions the participants voluntarily said the name of the target stimuli (voluntary responses) during the first experience and the second experience $r (22) = .797, p < .001$, as well as between the number of occasions the participants voluntarily saying the target stimuli emitted in the first experience and the third experience $r (22) = .823, p < .001$. Similarly, the number of occasions the participants voluntarily said the name of the target stimuli emitted in the second experience was correlated with the number of voluntary responses emitted in the third experience, $r (22) = .743, p < .001$. Although there was not a significant correlation between voluntarily saying the name of the target stimulus and listener responses in the first and third experiences, there was a significant correlation between number of occasions of voluntarily saying the name of the target stimulus emitted during the second experience and the percentage of listener responses $r (22) = .406, p =$
Table 2

Independent Samples t-Test across IFSP Status and Percentage of Correct Listener and Speaker Responses (Preliminary Analysis) for Experiment 1

<table>
<thead>
<tr>
<th>Outcome</th>
<th>IFSP</th>
<th>No IFSP</th>
<th>95% CI for Mean Difference</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M  SD n</td>
<td>M  SD n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listener 1</td>
<td>49.22 23.48 16</td>
<td>40.63 21.91 8</td>
<td>-29.24, 12.05</td>
<td>.397</td>
<td>-863</td>
<td>22</td>
</tr>
<tr>
<td>Listener 3</td>
<td>84.38 21.65 16</td>
<td>70.31 26.67 8</td>
<td>-35.05, 6.92</td>
<td>.178</td>
<td>-1.39</td>
<td>22</td>
</tr>
<tr>
<td>Speaker 1</td>
<td>12.50 17.68 16</td>
<td>9.38 12.94 8</td>
<td>-17.78, 11.53</td>
<td>.663</td>
<td>-442</td>
<td>22</td>
</tr>
<tr>
<td>Speaker 2</td>
<td>23.44 23.22 16</td>
<td>12.50 17.68 8</td>
<td>-30.34, 8.47</td>
<td>.255</td>
<td>-1.169</td>
<td>22</td>
</tr>
<tr>
<td>Speaker 3</td>
<td>42.41 32.51 16</td>
<td>17.20 25.82 8</td>
<td>-51.64, 3.21</td>
<td>.081</td>
<td>-1.831</td>
<td>22</td>
</tr>
</tbody>
</table>

* p < .05.
Table 3

*Independent Samples t-Test across Sex and Percentage of Correct Listener and Speaker Responses (Preliminary Analysis) for Experiment 1*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Female M</th>
<th>Female SD</th>
<th>Female n</th>
<th>Male M</th>
<th>Male SD</th>
<th>Male n</th>
<th>95% CI for Mean Difference</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listener 1</td>
<td>51.39</td>
<td>22.05</td>
<td>9</td>
<td>43.33</td>
<td>23.56</td>
<td>15</td>
<td>-12.10, 28.20</td>
<td>.638</td>
<td>.83</td>
<td>22</td>
</tr>
<tr>
<td>Listener 2</td>
<td>63.90</td>
<td>23.75</td>
<td>9</td>
<td>48.33</td>
<td>23.56</td>
<td>15</td>
<td>-5.11, 36.22</td>
<td>.836</td>
<td>1.56</td>
<td>22</td>
</tr>
<tr>
<td>Listener 3</td>
<td>90.28</td>
<td>17.43</td>
<td>9</td>
<td>73.33</td>
<td>25.38</td>
<td>15</td>
<td>-3.01, 36.63</td>
<td>.065</td>
<td>1.76</td>
<td>22</td>
</tr>
<tr>
<td>Speaker 1</td>
<td>9.72</td>
<td>15.02</td>
<td>9</td>
<td>12.50</td>
<td>17.03</td>
<td>15</td>
<td>-17.10, 11.50</td>
<td>.477</td>
<td>-.403</td>
<td>22</td>
</tr>
<tr>
<td>Speaker 2</td>
<td>16.67</td>
<td>16.54</td>
<td>9</td>
<td>21.67</td>
<td>24.76</td>
<td>15</td>
<td>-24.35, 14.35</td>
<td>.004</td>
<td>-.592*</td>
<td>22</td>
</tr>
<tr>
<td>Speaker 3</td>
<td>25.00</td>
<td>28.64</td>
<td>9</td>
<td>38.33</td>
<td>33.89</td>
<td>15</td>
<td>-41.39, 14.72</td>
<td>.312</td>
<td>-99</td>
<td>22</td>
</tr>
</tbody>
</table>

* p < .05.
Figure 1. Figure 1 displays the group differences across sex and mean percentage of correct listener and speaker responses for Experiment I. There was a significant difference between the percentage of correct, untaught speaker responses for the second experience between females and males. The percentage of correct speaker were significantly higher for males ($M= 21.67$) than females ($M= 16.67$).

Figure 2. Figure 2 displays the group differences across IFSP status and mean percentage of correct listener and speaker responses for Experiment I. There were no significant differences in listener and speaker responses across IFSP status (see Table 2).
Figure 3. Figure 3 displays the mean number of voluntarily saying the name of the target stimulus emitted across the three experiences in Experiment 1. Although they were correlated among themselves, there were no reliable associations between echoics and listener/speaker responses.

Figure 4. Figure 4 displays the correlations across the number of voluntarily saying the name of the target stimulus in Experiment 1. The second and third graphs display significant correlations.

Figure 5. Figure 5 displays the correlations across the number of voluntary echoics and the percentage of correct listener responses during Experience 2 for Experiment 1. This was the only significant correlation between echoics and listener/speaker responses.
Table 4

Pearson Correlation Matrix among Voluntary Responses, and Percentage of Correct Listener and Speaker Responses for Experiment 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Echoics 1</th>
<th>Echoics 2</th>
<th>Echoics 3</th>
<th>Listener 1</th>
<th>Listener 2</th>
<th>Listener 3</th>
<th>Speaker 1</th>
<th>Speaker 2</th>
<th>Speaker 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echoics 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echoics 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.797**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echoics 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.823**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.743**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listener 1</td>
<td>.090</td>
<td>.186</td>
<td>.392</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listener 2</td>
<td>.174</td>
<td>.406*</td>
<td>.274</td>
<td>.541**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listener 3</td>
<td>.034</td>
<td>.066</td>
<td>.017</td>
<td>.207</td>
<td>.597**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speaker 1</td>
<td>.094</td>
<td>.357</td>
<td>.201</td>
<td>.267</td>
<td>.516**</td>
<td>.084</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speaker 2</td>
<td>.170</td>
<td>.369</td>
<td>.106</td>
<td>.138</td>
<td>.465*</td>
<td>.115</td>
<td>.820**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speaker 3</td>
<td>.337</td>
<td>.213</td>
<td>.310</td>
<td>.229</td>
<td>.345</td>
<td>.284</td>
<td>.652**</td>
<td>.610**</td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$
** $p < .01$
There were no correlations between voluntarily saying the name of target stimuli and percentage of correct speaker responses across the three experiences (see Table 4). However, it is important to note that there were few accurate speaker responses overall.

**Listener and Speaker Responses**

There was a significant correlation at the .01 level between the listener responses and speaker responses during the second experience $r (22) = .465, p = .022$. Speaker responses during the first experience were correlated with listener responses during the second experience, $r (22) = .516, p = .010$. There was a significant, positive correlation between listener responses during the first experience and listener responses during the second experience $r (22) = .541, p = .006$. Listener responses during the second experience and listener responses during the third experience were correlated, $r (22) = .597, p = .002$.

There was a significant, positive correlation between speaker responses during the first experience and speaker responses during the second experience $r (22) = .820, p < .001$. Speaker responses during the first experience were correlated with the third experience $r (22) = .652, p = .001$ as well as between the second experience and speaker responses during the third experience $r (22) = .610, p = .002$.

*Figure 6.* Figure 6 displays the correlations among the listener responses across the three experiences for Experiment I. These data are reported as percent correct. All three graphs display significant correlations among the listener responses.
Figure 7. Figure 7 displays the correlations among the speaker responses across the three experiences for Experiment I. These data are reported as percent correct. All three graphs display significant correlations among the speaker responses.

Differences Across Experiences

To assess whether participants differed across the three naming experiences in accuracy of listener/speaker responses, I conducted repeated measures analysis of variance (RM ANOVA) across listener and speaker responses (see Tables 5-7). There was a significant difference among the three experiences in terms of correct, untaught listener responses $F(2, 22) = 18.703, p < .001$ as well as significant differences among the three experiences in terms of correct, untaught speaker responses $F(2, 22) = 11.789, p < .001$.

Experience 1 and 2. Post-hoc analyses (Bonferroni) revealed that although there was not a significant increase in listener responses from Experience 1 ($M = 46.354, SD = 4.667$) to Experience 2 ($M = 54.167, SD = 4.972$), $p = .314$, there was a significant increase in speaker responses from Experience 1 ($M = 11.458, SD = 3.272$) to Experience 2 ($M = 19.792, SD = 4.446$), $p = .011$. 

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Table 5

*Descriptive Statistics for Percentage of Correct Listener and Speaker Responses across Experience 1, 2, and 3 for Experiment I*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listener 1</td>
<td>46.354</td>
<td>4.66</td>
<td>36.699</td>
<td>56.009</td>
</tr>
<tr>
<td>Listener 2</td>
<td>54.167</td>
<td>4.972</td>
<td>43.881</td>
<td>64.452</td>
</tr>
<tr>
<td>Listener 3</td>
<td>79.688</td>
<td>4.865</td>
<td>69.623</td>
<td>89.752</td>
</tr>
<tr>
<td>Speaker 1</td>
<td>11.458</td>
<td>3.272</td>
<td>4.689</td>
<td>18.228</td>
</tr>
<tr>
<td>Speaker 2</td>
<td>19.792</td>
<td>4.446</td>
<td>10.594</td>
<td>28.989</td>
</tr>
<tr>
<td>Speaker 3</td>
<td>33.333</td>
<td>6.545</td>
<td>19.794</td>
<td>46.873</td>
</tr>
</tbody>
</table>

Table 6

*Bonferroni Comparison Across Percentage of Correct Listener 1, 2, and 3 for Experiment I*

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Mean Difference (percent)</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience 1 vs. 2</td>
<td>-7.813</td>
<td>4.627</td>
<td>-19.759</td>
<td>4.134</td>
</tr>
<tr>
<td>Experience 1 vs. 3</td>
<td>-33.333*</td>
<td>6.004</td>
<td>-48.835</td>
<td>-17.832</td>
</tr>
<tr>
<td>Experience 2 vs. 3</td>
<td>-25.521*</td>
<td>4.418</td>
<td>-36.928</td>
<td>-14.113</td>
</tr>
</tbody>
</table>

* p < 0.05

Table 7

*Bonferroni Comparison Across Percentage of Correct Speaker 1, 2, and 3 for Experiment I*

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Mean Difference (percent)</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience 1 vs. 2</td>
<td>-8.333*</td>
<td>2.570</td>
<td>-14.969</td>
<td>-1.698</td>
</tr>
<tr>
<td>Experience 1 vs. 3</td>
<td>-21.875*</td>
<td>5.061</td>
<td>-34.943</td>
<td>-8.807</td>
</tr>
<tr>
<td>Experience 2 vs. 3</td>
<td>-13.542*</td>
<td>5.208</td>
<td>-26.990</td>
<td>-0.094</td>
</tr>
</tbody>
</table>

* p < 0.05
Experience 2 and 3. Further, post-hoc analyses (Bonferroni) revealed that there was a significant increase from Experience 1 ($M = 46.354, SD = 4.667$) to Experience 3 ($M = 79.688, SD = 4.865$), $p < .001$ with similar trends between Experience 1 ($M = 11.458, SD = 3.272$) to Experience 3 ($M = 33.333, SD = 6.545$), $p = .001$.

Experience 1 and 3. Post-hoc analyses (Bonferroni) revealed that there was a significant increase between Experience 2 ($M = 54.167, SD = 4.972$) to Experience 3 ($M = 79.688, SD = 4.865$), $p < .001$ as well as a significant increase between Experience 2 ($M = 19.792, SD = 4.446$) to Experience 3 ($M = 33.333, SD = 6.545$), $p = .048$.

![Graph showing the percentage of correct responses across three experiences](image)

Figure 8. Figure 8 displays the significant differences across the three experiences of percent correct listener and speaker responses for Experiment I. The percentage of correct listener and speaker responses significantly increased across the three experiences, with the exception of Experience 1 to 2 for listener responses.

Discussion

The results of this study support the findings of previous literature on BiN that UniN emerges prior to joining of listener/speaker responses (Frank, 2018; Greer & Longano, 2010; Greer et al., 2005; Kleinert, 2018). Following successive naming experiences with identical stimuli and subsequent tests of listener/speaker responses, participants acquired three operants as a listener (~79% accurate listener responses) and one operant as a speaker (~33% accurate speaker responses).
There were no significant correlations between voluntary saying the name of the target stimulus and the accuracy of listener/speaker responses. Across the three experiences, the occasions for which the participants voluntarily said the name of the stimulus remained consistent across the three experiences (~4 voluntary responses). These data did not parallel changes to accuracy of listener/speaker responses; however, these responses were not echoic opportunities. That is, participants did not have consistent opportunities to echo during the experience. Skinner (1957) defined echoics as the immediate emission of an operant which holds point-to-point correspondence with the antecedent. Using the storybook naming experience, the participants did not receive consistent echoic opportunities, rather they received delayed opportunities to voluntarily say the target stimulus (e.g. experimenter said “Koop ate a hamburger” and participant voluntarily said “Koop”). Previous studies on BiN always presented auditory stimulus in proximity to visual stimulus (Frank, 2018; Fiorile & Greer, 2007; Gilic & Greer, 2011; Greer et al., 2005; Kleinert, 2018; Longano & Greer, 2015)

In examining trends across participants accurate speaker responses, it appears that following successive naming experiences, participants acquired one bidirectional operant (accurate speaker responses = 2/8 or approximately 33%). Further analysis of the target operants suggested the role of syllabic complexity, or how many syllables the target stimuli had, on the accuracy of speaker responses. Within one set of stimuli, there were target operants with one (e.g. “Koop”) and two (e.g. “Lavern”) syllables. Anecdotal findings suggest that participant demonstrated increased echoic clarity (Chavez-Brown, 2005; Choi, Keohane, & Greer, 2015) for one syllable operants (e.g. “Koop”) than two syllable operants (e.g. “Lavern”). Data revealed that regardless of controlling for syllables, the participants acquired the listener response (unidirectional relations emerged for three operants), but the speaker responses remained low
(bidirectional relations emerged for one operant). While this may suggest the immense role of echoic (proximate) opportunities in the acquisition of bidirectional operants, the trends in the data may be related to participant’s echoic clarity of auditory stimuli. That leads to future research questions related to the role of echoic clarity on accuracy of listener/speaker responses.

It is important to consider limitations and confounding variables in the study with regards to results. I conducted three naming experiences and subsequent probes, regardless of increases in correct, untaught responses. Previous literature on match-to-sample naming experiences conducted the experience until mastery was achieved (Greer et al., 2005) and the tact experience was presented only once (Kleinert, 2018; Lo, 2016), followed by assessments of untaught listener and speaker responses until participants demonstrated BiN. Recent data using an attempted storybook naming experience presented at international conference suggested trends with increased sessions and decreases in accurate responses (Farrell et al., 2018). They suggested that in the absence of reinforcement, more than three experiences resulted in decreased accurate responses. As this study emerged as an extension of the research from this conference presentation, I maintained the procedures. However, future studies are warranted on whether conducting multiple experiences, for the same stimuli, is effective or if repeated probe measures using novel stimuli may establish a stronger degree of speaker responses (Kleinert, 2018).

**Rationale for Experiment II**

Previous research on incidental language learning suggested the potential role of echoic responses in the emergence of BiN (Cao & Greer, 2019; Longano & Greer, 2015). Results of Experiment I suggest that the participants did not receive consistent opportunities to echo target stimuli, rather they were given the opportunity to voluntarily say the name of the target stimuli (delayed opportunities). Using common naming experience procedures, Match-to-Sample (MTS)
and tact experiences, auditory stimuli is presented in close proximity of visual stimuli (Kleinert, 2018; Longano & Greer, 2015). This may have limited the joining of listener and speaker responses, resulting in limited accurate speaker responses. These findings warrant future research studies. Results of Experiment I indicated that the acquisition of bidirectional operants may be related to the echoic clarity of target auditory stimuli. That is, is there a relation between participant’s phonemic responses to target auditory stimuli on the accuracy of listener/speaker responses?

In Experiment II, participants were first screened for echoic responses to contrived consonant-vowel-consonant (c-v-c). Target participants demonstrated conditioned reinforcement for echoics and reliably produced echoics throughout instructional sessions. Participants responses were then coded as full or partial echoic responses and paired with novel, familiar stimuli (e.g. cartoon characters). Then I conducted an ABAB reversal design to test for accuracy of listener/speaker responses using manipulation of phonemic responses that each participant demonstrated. The two conditions were full echoics (accurate phonemic correspondence) and partial echoics (partial phonemic correspondence).

**Research Questions for Experiment II**

1. Is there a relation between a child’s phonemic response to target auditory stimuli (echoic clarity) and accuracy of listener/speaker responses (demonstration of BiN)?
Chapter III

EXPERIMENT II: EXPERIMENTAL COMPARISON OF ECHOIC CLARITY ON ACCURACY OF UNTAUATED LISTENER AND SPEAKER RESPONSES

Method

The settings, participant inclusion criteria, probe session materials, definition of dependent variables, and procedure of naming experience sessions were the same as Experiment I. Methodological differences in Experiment II included (a) the data collection procedures during naming experiences, (b) the criterion for emergence of UniN and BiN, (c) different naming probe procedures, and (d) I conducted a single-case experimental design.

Participants

Experimenters selected four typically developing students from an integrated Early Intervention classroom, all included as participants in Experiment I and attended the same school settings at the time of this experiment (see Table 8). All participants were monolingual, American English-speaking toddlers. Results of the Experiment I suggested that none of the participants demonstrated BiN following three, consecutive storybook naming experiences and naming probes. Results of Experiment I suggested that anecdotally, participants acquired untaught speaker responses for words which had one syllable (e.g. “Koop”) versus two syllables (e.g. “Lavern”). Therefore, they were candidates for a second experiment to test whether echoic clarity is a sensitive measure to accuracy of listener/speaker responses.

Prior to the onset of the study, we randomly assigned participants into dyads to enter intervention simultaneously. Participants A and B made up Dyad 1 and Participants C and D made up Dyad 2. Each participant within the dyad experienced intervention sessions
counterbalanced, such that Participant A and C experienced intervention in the following sequence ABAB, whereas Participant B and D experienced intervention in BABA sequence.

Table 8

*Characteristics of the Participants for Experiment II*

<table>
<thead>
<tr>
<th>Participants (dyad)</th>
<th>Age (Months)</th>
<th>Gender</th>
<th>Grade</th>
<th>Level of Verbal Behavior</th>
<th>Common Cusps and Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant A</td>
<td>2.5 (30)</td>
<td>M</td>
<td>EI</td>
<td>Listener/Speaker</td>
<td>Teacher Presence Results in Instructional Control, Independent Tacts, Conditioned Reinforcement for Adults Faces/Voices, Listener Literacy, Conditioned Reinforcement for 2D stimuli</td>
</tr>
<tr>
<td>Dyad 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant B</td>
<td>2.5 (30)</td>
<td>F</td>
<td>EI</td>
<td>Listener/Speaker</td>
<td></td>
</tr>
<tr>
<td>Dyad 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant C</td>
<td>2.6 (31)</td>
<td>M</td>
<td>EI</td>
<td>Listener/Speaker</td>
<td></td>
</tr>
<tr>
<td>Dyad 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant D</td>
<td>2.2 (26)</td>
<td>F</td>
<td>EI</td>
<td>Listener/Speaker</td>
<td></td>
</tr>
<tr>
<td>Dyad 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Relevant cusps and capabilities were common among all participants as inclusion criterion for the study.

**Setting and Materials**

Setting and materials used for naming experiences and subsequent probes were identical to the settings identified in Experiment I.

**Dependent Variables**

In Experiment II, I measured the same variables from Experiment I: number of occasions the participants voluntarily said the name of the target stimulus during the naming experience and the accuracy of listener and speaker responses. Procedural modifications from Experiment I to II included (a) increased the opportunities to respond as a listener from 2 to 3 per stimulus (9
total), (b) more stringent criterion for presence of UniN and BiN (100% accuracy for listener/speaker compared to 75% in Experiment I).

Independent Variable: Echoic Clarity of Auditory Stimuli

The independent variables of the study were two different conditions under which naming experiences and probes were conducted. The two conditions were (A) full echoic clarity and (B) partial echoic clarity and were defined by participant-specific echoic clarity, or phonemic accuracy of echoic responses, of nonsense, developmentally appropriate c-v-c words (Goldman Fristoe Test of Articulation-2, 2000). Throughout the remainder of the paper, the two conditions will be referred to as (A) Full and (B) Partial.

I tested the percentage of correct listener/speaker responses across the following two conditions: full echoic clarity and partial echoic clarity. Condition (A) Full was defined as contrived, word-object relations for which participants emitted full echoic responses during echoic screenings (e.g. experimenter says “Pid” and participant emits echoic response in which all three phonemes are present, “pid”). Condition (B) Partial was defined as contrived, word-object relations for which participants emitted partial echoic responses during echoic screenings (e.g. experimenter says “Pid” and participant emits echoic response in which two of the three phonemes are present, “id”). Each intervention session consisted of a naming experience in which experimenters read a story giving the participant 18 opportunities to simultaneously view the visual stimuli while the experimenter labeled the name paired with the stimulus (e.g. “this is Pid”). Experimenters delivered the naming experience using the same procedures as described in Experiment I.
Table 9

List of Words Derived from Target Isolation Sounds for Experiment II

<table>
<thead>
<tr>
<th>English</th>
<th>IPA</th>
<th>English</th>
<th>IPA</th>
<th>English</th>
<th>IPA</th>
<th>English</th>
<th>IPA</th>
<th>English</th>
<th>IPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bam</td>
<td>/Bæm/</td>
<td>Pod</td>
<td>/Pæd/</td>
<td>Bep</td>
<td>/Bɛp/</td>
<td>Gip</td>
<td>/Gɪp/</td>
<td>Pem</td>
<td>/Pɛm/</td>
</tr>
<tr>
<td>Don</td>
<td>/Dan/</td>
<td>Gen</td>
<td>/Gɛn/</td>
<td>Neb</td>
<td>/Nɛb/</td>
<td>Mab</td>
<td>/Mæb/</td>
<td>Gid</td>
<td>/Gɪd/</td>
</tr>
<tr>
<td>Mag</td>
<td>/Mæɡ/</td>
<td>Dim</td>
<td>/Dɪm/</td>
<td>Mep</td>
<td>/Mɛp/</td>
<td>Deb</td>
<td>/Dɛb/</td>
<td>Bid</td>
<td>/Bɪd/</td>
</tr>
<tr>
<td>Nug</td>
<td>/Næɡ/</td>
<td>Med</td>
<td>/Mɛd/</td>
<td>Gub</td>
<td>/Gʌb/</td>
<td>Ban</td>
<td>/Bæn/</td>
<td>Nog</td>
<td>/Nɑɡ/</td>
</tr>
<tr>
<td>Pom</td>
<td>/Pɑm/</td>
<td>Bup</td>
<td>/Bʌp/</td>
<td>Beb</td>
<td>/Bɛb/</td>
<td>Dap</td>
<td>/Dæp/</td>
<td>Bud</td>
<td>/Bʌd/</td>
</tr>
<tr>
<td>Gen</td>
<td>/Gɛn/</td>
<td>Nod</td>
<td>/Nɑd/</td>
<td>Dem</td>
<td>/Dɛm/</td>
<td>Pip</td>
<td>/Pɪp/</td>
<td>Pud</td>
<td>/Pʌd/</td>
</tr>
<tr>
<td>Mib</td>
<td>/Mɪb/</td>
<td>Gup</td>
<td>/Gʌp/</td>
<td>Pim</td>
<td>/Pɪm/</td>
<td>Bip</td>
<td>/Bɪp/</td>
<td>Mub</td>
<td>/Mʌb/</td>
</tr>
<tr>
<td>Nag</td>
<td>/Næɡ/</td>
<td>Pib</td>
<td>/Pɪb/</td>
<td>Mon</td>
<td>/Mɒn/</td>
<td>Nib</td>
<td>/Nɪb/</td>
<td>Pum</td>
<td>/Pʌm/</td>
</tr>
<tr>
<td>Gub</td>
<td>/Gʌb/</td>
<td>Bid</td>
<td>/Bɪd/</td>
<td>Pun</td>
<td>/Pʌn/</td>
<td>Gem</td>
<td>/Gɛm/</td>
<td>Dun</td>
<td>/Dʌn/</td>
</tr>
<tr>
<td>Bon</td>
<td>/Bɒn/</td>
<td>Dib</td>
<td>/Dɪb/</td>
<td>Nup</td>
<td>/Nʌp/</td>
<td>Dab</td>
<td>/Dæb/</td>
<td>Mub</td>
<td>/Mʌb/</td>
</tr>
<tr>
<td>Din</td>
<td>/Dɪn/</td>
<td>Nep</td>
<td>/Nɛp/</td>
<td>Gim</td>
<td>/Gɪm/</td>
<td>Mem</td>
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<td>Pum</td>
<td>/Pʌm/</td>
</tr>
<tr>
<td>Pug</td>
<td>/Pʌɡ/</td>
<td>Mig</td>
<td>/Mɪɡ/</td>
<td>Pep</td>
<td>/Pɛp/</td>
<td>Gam</td>
<td>/Gæm/</td>
<td>Dun</td>
<td>/Dʌn/</td>
</tr>
<tr>
<td>Dup</td>
<td>/Dʌp/</td>
<td>Geb</td>
<td>/Gɛb/</td>
<td>Bib</td>
<td>/Bɪb/</td>
<td>Bid</td>
<td>/Bɪd/</td>
<td>Mun</td>
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<tr>
<td>Mim</td>
<td>/Mɪm/</td>
<td>Nud</td>
<td>/Nʌd/</td>
<td>Peb</td>
<td>/Pɛb/</td>
<td>Nab</td>
<td>/Næb/</td>
<td>Gib</td>
<td>/Gɪb/</td>
</tr>
<tr>
<td>Nem</td>
<td>/Nɛm/</td>
<td>Mip</td>
<td>/Mɪp/</td>
<td>Gep</td>
<td>/Gɛp/</td>
<td>Din</td>
<td>/Dɪn/</td>
<td>Mid</td>
<td>/Mɪd/</td>
</tr>
<tr>
<td>Dub</td>
<td>/Dʌb/</td>
<td>Pim</td>
<td>/Pɪm/</td>
<td>Dip</td>
<td>/Dɪp/</td>
<td>Pid</td>
<td>/Pɪd/</td>
<td>Nud</td>
<td>/Nʌd/</td>
</tr>
<tr>
<td>Nim</td>
<td>/Nɪm/</td>
<td>Bun</td>
<td>/Bʌn/</td>
<td>Bum</td>
<td>/Bʌm/</td>
<td>Pem</td>
<td>/Pɛm/</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Table 2 displays the words derived from the Speech Sound Development Norms from the Goldman Fristoe Test of Articulation (2000). For students of 24 months of age I selected the following sounds: /g/, /b/, /p/, /m/, and /n/. Prior to intervention, experimenters assessed the participants’ echoic responses for the entire list of words at least twice.
At the onset of the study, I assessed echoic responses for identical nonsense words across the participants simultaneously; however, each participant’s target stimuli during naming experiences were unique to that participant’s echoic repertoire. That is, experimental conditions were participant-specific, such that auditory stimuli included in (A) Full phases for Participant A were selected based on Participant A’s echoic clarity. See Tables 10-13 for participant-specific echoic responses.

Data Collection

Data were collected using the procedures described in Experiment I during naming experiences and subsequent probes. During echoic screenings data were reported using two codes: Full (“F”), to define responses which held point-to-point correspondence with the experimenter’s antecedent, or partial (“P”), which defined responses for which two of the three phonemes were present.

Design

The design of the study was a counterbalanced ABAB/BABA reversal design across participants (see Figure 10). Phase A (Full) was defined as targeted auditory stimuli for which the participant emitted full echoics (full echoic clarity). Phase B (Partial) was defined as targeted auditory stimuli for which the participant emitted partial echoics (partial echoic clarity). Participants A and C experienced intervention conditions in the following sequence: ABAB and Participants B and D experienced intervention conditions in the following sequence: BABA. I defined one phase of intervention as three consecutive naming experiences and subsequent probe for the target set of stimuli.

For Participants A and C, intervention was as follows: three naming experiences/probes for full echoic sets, three naming experiences/probes for partial echoic sets, three naming
Figure 9. Figure 9 shows the complete sequence of the design across participants for Experiment II (ABAB reversal). Each intervention session consisted of a storybook experience and a subsequent probe (2 hours following experience). Criterion for presence of BiN was considered 100% across 9 listener responses and 100% across 3 speaker responses. Within each dyad, participants order of intervention were counterbalanced such that Participants A and C received Full (A), Partial (B), Full (A), and Partial (B) and Participants B and D experienced intervention in opposite order.
experiences/probes for full echoics, and three naming experiences/probes for partial echoic sets. For Participants B and D, intervention was as follows: three naming experiences/probes for partial echoic sets, three naming experiences/probes for full echoic sets, three naming experiences/probes for partial echoics, and three naming experiences/probes for full echoic sets.

**Procedures**

The procedure consisted of (1) two pre-intervention echoic screenings across all participants simultaneously, using the words derived from Speech Sound Norm words derived from the *Goldman Fristoe Test of Articulation-2* (2000; see Table 9), (2) Dyad 1 entered intervention (Participant A and B) and Dyad 2 (Participant C and D) received a third echoic screening, (3) Participant A received 3 three naming experiences/probes for (A) Full and Participant B received 3 three naming experiences/probes for (B) Partial, (4) Dyad 2 entered intervention; Dyad 1 received replication of phases with novel stimuli, and (5) Dyad 2 received replication of phases with novel stimuli. Figure 10 shows the full sequence of the study.

**Echoic screening.** Prior to the onset of intervention, experimenters conducted echoic screenings across participants (see Table 9). Experimenters contrived 84 consonant-vowel-consonant words derived from *Speech Sound Norms* from the *Goldman Fristoe Test of Articulation-2* (2000). We included the following consonant sounds: /b/, /p/, /m/, /n/, and /g/ along with all vowel sounds. At the onset of the study, each participant received two consecutive echoic screenings to assess for maturation. Experimenters classified each echoic as a partial or full echoic. We defined a partial echoic as one which included two of the three target phonemes (e.g. “up” instead of “bup”). We defined a full echoic as one which included all three target phonemes (e.g. “bup” for “bup”). For Dyad 1, two observers scored each video to ensure reliability of the classification. Following scoring, experimenters identified words echoed with
full phonemic correspondence or partial echoic correspondence across both screenings. These selected words then were assigned novel, familiar stimuli which became targeted for naming probes (see Tables 10-13). Dyad 2 received a third echoic screening to assess for changes to echoic responses during Dyad 1’s initial intervention phase. I scored Dyad 2 using the same procedures as Dyad 1.

**Successive naming experience with identical stimuli (SNEIS).** All intervention phases consisted of three naming experiences and subsequent probes with the same stimuli, using a storybook. The naming experience procedures mirrored those used in Experiment I, with the exception of three stimuli per set versus four. Each experience consisted of 18 opportunities to hear the name of the stimulus while observing the stimulus imbedded in a made-up story (e.g. “Pid ate a cookie”). Two-hours following a naming experience for a set of stimuli (see Figure 10) we conducted listener (selection) and speaker (tact) probes. The listener probes consisted of three opportunities to select the three target stimuli from a field of three (e.g. “point to Pid”), for a total of nine listener opportunities. Criterion for presence of unidirectional Naming was considered 100% correct, untaught listener responses. The speaker probes consisted of opportunities to label the three target stimuli in a field of one (e.g. “Pid”), however, the total number of responses was contingent on correct responses, for a total ranging from three to six opportunities. Criterion for presence of BiN was considered 100% correct, untaught listener and speaker responses.

Participants A and C experienced intervention sessions in the following order: full (A), partial (B), full (A), and partial (B). Participants B and D experienced intervention sessions in the reverse order, partial (B), full (A), partial (B), and full (A). See Tables 10-13 for participant-specific target, contrived words with attached visual stimuli. Each dyad was counterbalanced to
eliminate practice effects and compare the correct responses for full echoics versus partial echoics.

Table 10

*Target Stimuli for Each Intervention Phase for Participant A for Experiment II*

<table>
<thead>
<tr>
<th>Full Set 1</th>
<th>Partial Set 1</th>
<th>Full Set 2</th>
<th>Partial Set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don</td>
<td>Bam</td>
<td>Bup</td>
<td>Nug</td>
</tr>
<tr>
<td>Pod</td>
<td>Mag</td>
<td>Mim</td>
<td>Mib</td>
</tr>
<tr>
<td>Gip</td>
<td>Gub</td>
<td>Din</td>
<td>Bid</td>
</tr>
</tbody>
</table>

*Note.* Table 4 shows the target, contrived words paired with novel, familiar stimuli used for the intervention across Participant A. Following echoic screenings (see Table 9), I categorized the words based on full and partial responses as scored by at least two observers. I prioritized words for which I scored with 100% agreement, although inclusion criterion was 75% agreement. I then randomized words into sets for consecutive naming experiences to ensure no repeated beginning or end sounds (e.g. Map and Mup would not occur in the same set). Following assigning words into sets, I paired the words with familiar stimuli to conduct successive naming experiences. I counterbalanced the stimuli across dyads. During the experience, I read a story in which I gave the participant 6 opportunities to hear us pair the contrived words above as the name for the paired, familiar stimuli, for a total of 18 experiences (e.g. “This is Don”). Two hours later, I conducted the probe, during which participants were asked to respond as a listener and speaker for the target stimuli. There were 3 opportunities across the 3 stimuli with criterion being 100% across one session for the listener. For the speaker, I determined total opportunities to label each stimulus based on participant responding for a total number of 3 to 6 opportunities. Criterion was considered 100% across one opportunity to label the three stimuli.
Table 11

Target Stimuli for Each Intervention Phase for Participant B for Experiment II

<table>
<thead>
<tr>
<th>Partial Set 1</th>
<th>Full Set 1</th>
<th>Partial Set 2</th>
<th>Full Set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen</td>
<td>Bam</td>
<td>Bid</td>
<td>Nug</td>
</tr>
<tr>
<td>Mab</td>
<td>Mag</td>
<td>Neb</td>
<td>Pom</td>
</tr>
<tr>
<td>Bup</td>
<td>Don</td>
<td>Gep</td>
<td>Mib</td>
</tr>
</tbody>
</table>

Note. Table 5 shows the target, contrived words paired with novel, familiar stimuli used for the intervention across Participant B. Following echoic screenings (see Table 9), I categorized the words based on full and partial responses as scored by at least two observers. I prioritized words for which I scored with 100% agreement, although inclusion criterion was 75% agreement. I then randomized words into sets for successive naming experiences to ensure no repeated beginning or end sounds (e.g. Map and Mup would not occur in the same set). Following assigning words into sets, I paired the words with familiar stimuli to conduct consecutive naming experiences. I counterbalanced the stimuli across dyads. During the experience, I read a story in which I gave the participant 6 opportunities to hear us pair the contrived words above as the name for the paired, familiar stimuli, for a total of 18 experiences (e.g. “This is Don”). Two hours later, I conducted the probe, during which participants were asked to respond as a listener and speaker for the target stimuli. There were 3 opportunities across the 3 stimuli with criterion being 100% across one session for the listener. For the speaker, I determined total opportunities to label each stimulus based on participant responding for a total number of 3 to 6 opportunities. Criterion was considered 100% across one opportunity to label the three stimuli.
Table 12

*Target Stimuli for Each Intervention Phase for Participant C for Experiment II*

<table>
<thead>
<tr>
<th>Full Set 1</th>
<th>Partial Set 1</th>
<th>Full Set 2</th>
<th>Partial Set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nug</td>
<td>Don</td>
<td>Pug</td>
<td>Mim</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pom</td>
<td>Bid</td>
<td>Gip</td>
<td>Gid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bip</td>
<td>Mib</td>
<td>Bam</td>
<td>Nog</td>
</tr>
</tbody>
</table>

*Note.* Table 6 shows the target, contrived words paired with novel, familiar stimuli used for the intervention across Participant C. Following echoic screenings (see Table 9), I categorized the words based on full and partial responses as scored by at least two observers. I prioritized words for which I scored with 100% agreement, although inclusion criterion was 75% agreement. I then randomized words into sets for successive naming experiences to ensure no repeated beginning or end sounds (e.g. Map and Mup would not occur in the same set). Following assigning words into sets, I paired the words with familiar stimuli to conduct consecutive naming experiences. I counterbalanced the stimuli across dyads. During the experience, I read a story in which I gave the participant 6 opportunities to hear us pair the contrived words above as the name for the paired, familiar stimuli, for a total of 18 experiences (e.g. “This is Don”). Two hours later, I conducted the probe, during which participants were asked to respond as a listener and speaker for the target stimuli. There were 3 opportunities across the 3 stimuli with criterion being 100% across one session for the listener. For the speaker, I determined total opportunities to label each stimulus based on participant responding for a total number of 3 to 6 opportunities. Criterion was considered 100% across one opportunity to label the three stimuli.
Table 13

Target Stimuli for Each Intervention Phase for Participant D for Experiment II

<table>
<thead>
<tr>
<th>Partial Set 2</th>
<th>Full Set 2</th>
<th>Partial Set 2</th>
<th>Full Set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deb</td>
<td>Pom</td>
<td>Mig</td>
<td>Don</td>
</tr>
<tr>
<td>Ban</td>
<td>Gub</td>
<td>Nib</td>
<td>Bam</td>
</tr>
<tr>
<td>Mem</td>
<td>Mag</td>
<td>Pod</td>
<td>Pip</td>
</tr>
</tbody>
</table>

Note. Table 7 shows the target, contrived words paired with novel, familiar stimuli used for the intervention across Participant D. Following echoic screenings (see Table 9), I categorized the words based on full and partial responses as scored by at least two observers. I prioritized words for which I scored with 100% agreement, although inclusion criterion was 75% agreement. I then randomized words into sets for successive naming experiences to ensure no repeated beginning or end sounds (e.g. Map and Mup would not occur in the same set). Following assigning words into sets, I paired the words with familiar stimuli to conduct consecutive naming experiences. I counterbalanced the stimuli across dyads. During the experience, I read a story in which I gave the participant 6 opportunities to hear us pair the contrived words above as the name for the paired, familiar stimuli, for a total of 18 experiences (e.g. “This is Don”). Two hours later, I conducted the probe, during which participants were asked to respond as a listener and speaker for the target stimuli. There were 3 opportunities across the 3 stimuli with criterion being 100% across one session for the listener. For the speaker, I determined total opportunities to label each stimulus based on participant responding for a total number of 3 to 6 opportunities. Criterion was considered 100% across one opportunity to label the three stimuli.
Interobserver agreement (IOA)

Across naming experience/probe sessions, we collected data on the percentage of interobserver agreement (IOA) using a second, independent observer. IOA was calculated using point-by-point procedures, dividing the total number of correct responses recorded by one observer (the lower of the two totals) by the total number of correct responses recorded by the other observer and multiplying the result by 100 percent.

During echoic screenings, we collected IOA for 100% of sessions across Participants A, B, C, and D, with at least 75% agreement across the contrived words selected for intervention. For Participant A, IOA was collected for 16% of naming experiences and 33% of naming probes with 100% agreement. For Participant B, IOA was collected for 44% of naming experiences and 78% of naming probes with 97% agreement. For Participant C, IOA was collected for 8% of naming experiences and 25% of naming probes with 100% agreement. For Participant D, IOA was collected for 66% of naming experiences and 66% of naming probes with 100% agreement.

Results

Results from Experiment II are displayed in Figures 11-14. The results are discussed in temporal order by participant to describe the effects of the intervention on voluntarily saying the name of target stimuli and accuracy of listener/speaker responses. During each naming experience, participants had 18 total opportunities to voluntarily say the name of the target stimuli, referred to as voluntary responses.
Figure 10. Figure 10 displays the cumulative number of echoics emitted across each target operant across Participants A, B, C, and D for Experiment II. The x-axis displays the sessions, not in sequential order, but as a cumulative number of echoics emitted for each operant across the three naming experiences. Each phase of intervention consisted of three naming probes which included an experience and a subsequent probe. During the experience, each participant was given six opportunities to simultaneously hear the teacher label the name of the character while attending to a visual stimulus across three target stimuli, for a total of 18 opportunities. Each naming experience and probe was presented across three consecutive school days. There was no criterion attached to the echoics.
Figure 11. Figure 11 displays the number of echoic emitted across each condition for full and partial echoics across Participants A, B, C, and D. During each phase, I conducted three naming experiences and subsequent probes for Experiment II. The x-axis displays the session number per condition. During the experience, each participant received six opportunities to simultaneously hear the experimenter label the name of the character while attending to a visual stimulus across three target stimuli, for a total of 18 opportunities. There was no criterion attached to echoic responses.
**Participant A.** Participant A emitted an average of 9 voluntary responses during the first Full phase, 7 during the first Partial phase, 6 during the second Full phase, and 8 during the final Partial phase. Participant A’s voluntary responses were consistent across both Partial phases, but for Full phases, they nearly decreased to an average of 6 voluntary responses.

During the initial Full phase, Participant A emitted increased listener responses, 66%, 78%, and 100%, across three experiences, respectively. Speaker responses also increased from 0% to 100% on the third experience. Across Partial Phase, listener responses mirrored the first Full Phase in increasing to 100%, as did speaker responses (0%, 44%, 66%). During the second Full Phase, Participant A’s listener responses increased consistently to 100% across the three experiences, while speaker responses increased to 11% and remained for the third experience. In the final phase, Participant A emitted high levels of listener responses (100%) and no speaker responses.

**Participant B.** Participant B emitted an average of 8 voluntary responses during the first Partial phase, 5 during the first Full phase, 7 during the second Partial phase, and 6 during the second Full phase. Participant B’s voluntary responses remained stable across both Full and Partial phases.

Participant B emitted variable levels of correct, untaught listener and speaker responses. During the initial Partial Phase, Participant B emitted 22%, 66%, and 0% selection responses, with 0%, 22%, and 0% speaker responses. During the initial Full Phase, she emitted increasing listener levels with selection responses nearing criterion-level (78%) across three sessions, with speaker responses remaining at 11%. Participant B emitted decreasing listener responses (78%, 78%, and 22%) with 0% speaker responses. during her second partial phase. During the final
Figure 12. Figure 12 displays the percentage of correct, untaught listener and speaker responses across naming probes for Experiment II. These data report correct listener and speaker responses across each of the three sessions for all phases. Criterion was considered 100% across listener and speaker responses. I gave participants three opportunities to respond as a listener to each of the three stimuli, for a total of nine opportunities. For speaker responses, I delivered one opportunity to label each of the three stimuli. Given no response or an incorrect response, I delivered a subsequent opportunity. If data suggested two consecutive minuses, I considered the participant not to have acquired the speaker response.
phase (full) she emitted variable level listener responses (55%, 78%, and 22%) with 11% speaker
during the third session.

**Participant C.** Participant C emitted no voluntary responses across the 12 naming
experiences. During Phase A, Participant C emitted criterion level listener responses, 66%, 77%,
and 100%, for experience 1, 2, and 3, respectively. For speaker responses, he emitted 33%,
100%, and 44%, across the three experiences, respectively. During Phase B, he emitted 44%,
100%, and 88% listener responses across the three experiences and 0% speaker responses across
the three experiences. He emitted 0 untaught speaker responses across the remainder of phases;
however, listener responses remained near criterion, Phase A, 33%, 100%, 88%, and Phase B,
44%, 66%, and 55%.

**Participant D.** During the naming experiences, Participant D emitted an average of 3
voluntary responses during the first Partial phase, 7 during the first Full phase, 6 during the
second Partial phase, and 2 during the second Full phase. She emitted few voluntary responses
during the terminal full condition, for which she demonstrated BiN.

Participant D emitted criterion-level listener responses across three of the four conditions
(first partial condition and both full conditions). During the first partial condition, she emitted
89%, 78%, and 100% correct listener responses with variable speaker responses (22%, 56%, and
11%). Full Phase listener responses remained at 100% across the three experiences with speaker
increasing from 22% to 56%. A second partial phase revealed slightly lower than criterion-level
responding (89%, 56%, and 89%) with speaker increasing to 56%. During the final full
condition, Participant D demonstrated BiN during the first experience when she emitted 100% listener and speaker responses.
Figure 13. Figure 13 displays the percentage of correct, untaught listener and speaker responses across naming probes for the terminal session for Experiment II. These data report correct listener and speaker responses across each stimulus for three successive naming probes. Criterion was considered 100% across listener and speaker responses. I gave participants three opportunities to respond as a listener to each of the three stimuli, for a total of nine opportunities. For speaker responses, I delivered one opportunity to label each of the three stimuli. Given no response or an incorrect response, I delivered a subsequent opportunity. If data suggested two consecutive minuses, I considered the participant not to have acquired the speaker response.
Discussion

Results of Experiment II indicated that echoic clarity was not related to degrees of BiN, as measured by accuracy of listener/speaker responses. Across the two conditions, there were no reliable differences in accuracy of listener/speaker responses between Full and Partial phases. That is, manipulation of phonemic responses that each participant demonstrated did not affect their acquisition of bidirectional operants. Based on findings of previous literature related to echoic training (Cao & Greer, 2019), I hypothesized that accuracy of listener/speaker responses would be significantly higher given full echoic clarity (Full phase) than partial echoic clarity (Partial phase).

All four participants demonstrated increased correct listener responses within each phase, further validating the findings of Experiment I and previous BiN literature suggesting UniN emerges prior to BiN (Frank, 2018; Greer et al., 2005; Longano & Greer, 2015; Kleinert, 2018). However, trends in accurate speaker responses were variable within each phase, suggesting bidirectional operants did not emerge as a function of echoic clarity, with the exception of Participant D. Participant D acquired BiN as a function of repeated, consecutive naming experiences regardless of echoic clarity (see Figure 14).

Similar to Experiment I, voluntarily saying the name of the stimuli was also not affected by echoic clarity and was not reliably different across the two conditions. Participants emitted similar levels of voluntary responses regardless of echoic clarity, however, the same limitations of Experiment I remain. The target auditory stimuli were often in-proximate to the participant’s opportunity to voluntarily say the target auditory stimulus. Further, Participant C emitted no voluntary responses across all conditions.
There were some limitations in Experiment II to be addressed. First, in delivering successive naming experiences, the ABAB reversal design did not control for sequence effect. Previous literature on BiN suggest that successive novel naming experiences lead to joining of listener and speaker responses (Kleinert, 2018; Lo, 2016). This must be considered in examining results of Experiment II, especially with regard for Participant D. In conducting consecutive naming experiences, I could not control for learning occurring as a function of repeated measures. It appeared this limitation affected only Participant D as she acquired BiN as a function of consecutive naming experiences. The remaining three participants demonstrated variable listener/speaker responses across the conditions, suggesting that the findings remain valid. Further, increased participants demonstrating similar findings could increase believability of the findings.

In Experiment II, researchers focused on manipulating one syllable auditory stimuli only. Future research on the role of echoic clarity should conduct similar measures to compare accuracy of listener/speaker responses across single syllable and multi-syllabic auditory stimuli. Increasing the complexity of auditory stimuli may result in reliable differences in acquisition of bidirectional operants.

**Rationale for Experiment III**

Based on results of the group descriptive analysis and Experiment II, it is evident that consecutive naming experiences using the storybook resulted in reliable UniN, but not BiN. Findings suggest that at this point in verbal development, acquiring bidirectional operants via a storybook is not an effective procedure. This warrants future studies to identify where in the verbal developmental trajectory one can acquire bidirectional operants from a storybook.
Further, findings of Experiment II eliminate the potential for echoic clarity to be considered as a variable when assessing for BiN.

Results of Experiment II indicated that research gaps identified in Experiment I related to role of proximity of auditory stimuli to visual stimuli remain and warrant future studies. Voluntarily saying the name of the target stimulus functioning to join listener and speaker responses is not likely to occur when other auditory stimuli occur between presence of target auditory stimulus and visual stimulus. In the absence of a proximate, voluntary response opportunity, the listener response emerged, but not the speaker. Decades of research suggest the role of conditioned reinforcement for both auditory and visual stimuli in the explosion of language acquisition known as BiN (Longano & Greer, 2010; Miguel, 2016). Would different procedures result in different relations between voluntary echoic responses (conditioned reinforcement for echoic responses) and untaught speaker responses (conditioned reinforcement for correspondence with see-say)? The data reported herein and the discussion regarding the source of reinforcement for echoics and emergence of BiN warrant continued research into procedures for conditioning auditory and visual stimuli.

Findings of applied science research suggest the role of conditioning reinforcement via stimulus-stimulus pairings on the emergence of new conditioned reinforcers and eventually the emergence of BiN (Longano & Greer, 2015). With regards to the findings of Experiments I and II, how does the order of presentation of visual and auditory stimuli relate to the emergence of bidirectional naming for toddler-aged participants. That is, does the order of presentation of visual stimuli (picture) and auditory stimuli (spoken word) affect the emergence of bidirectional operants for toddler-aged children. Findings will add to the literature on BiN by contributing to
whether or not visual and auditory stimuli must be presented simultaneously in order for bidirectional operants to emerge.

**Research Questions for Experiment III**

1. What is the role of temporal proximity of presentation of visual and auditory stimuli on accuracy of listener/speaker responses for toddler-aged participants?
Chapter IV

EXPERIMENT III: THE EFFECTS OF TEMPORAL PROXIMITY OF VISUAL AND AUDITORY STIMULI ON THE ACCURACY OF UNTRAINED LISTENER AND SPEAKER RESPONSES

Method

Participants

Experimenters selected six students from an integrated Early Intervention classroom, all of whom participated in either Experiment I and II (see Table 1). They ranged in age from 32- to 38-months-old. Three of the participants were neurotypically developing and 3 were classified with Individualized Family Service Plans (IFSP). Participants A and D were bilingual (Mandarin and Spanish, respectively) speakers and the remaining participants were monolingual American English-speakers. All of the participant demonstrated the prerequisites for acquisition of BiN, specifically conditioned reinforcement for 2D stimuli, generalized match-to-sample, and independent mands/tacts.

Results of the first two studies suggested that these participants reliably demonstrated UniN, did not demonstrate BiN via consecutive storybook naming experiences. Findings further suggested that controlling for echoic clarity did not affect the degree of BiN demonstrated by the participants. For the current study, I selected participants whose instructional history included storybook naming experiences to measure the effects of a different procedure on the joining of listener and speaker. We selected these participants as they reliably demonstrated unidirectional naming (UniN), or the acquisition of untaught listener responses following a naming experience. See Table 14 for a description of participant characteristics.

Setting and Materials
Settings used for naming experiences and subsequent probes were identical to those in Experiments I and II. Materials used during pre- and post-intervention naming experience and Table 14

*Characteristics of the Participants for Experiment III*

<table>
<thead>
<tr>
<th>Participants</th>
<th>Age (Months)</th>
<th>Gender</th>
<th>Grade</th>
<th>Classification</th>
<th>Common Cusps and Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.9 (34)</td>
<td>F</td>
<td>Preschool</td>
<td>--</td>
<td>Teacher Presence Results in Instructional Control, Independent Mands and Tacts, Conditioned Reinforcement for Adults Faces/Voices, Listener Literacy, Conditioned Reinforcement for 2D, Generalized Match-to-Sample, Unidirectional Naming (UniN)</td>
</tr>
<tr>
<td>B</td>
<td>3.0 (36)</td>
<td>F</td>
<td>Preschool</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3.1 (37)</td>
<td>M</td>
<td>EI</td>
<td>IEP</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3.0 (36)</td>
<td>F</td>
<td>EI</td>
<td>IEP</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>3.2 (38)</td>
<td>M</td>
<td>EI</td>
<td>IEP</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>2.8 (32)</td>
<td>M</td>
<td>EI</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* All participants demonstrated common, relevant cusps/capabilities as defined by inclusion criterion.

Subsequent probes included pre-constructed data sheets with the names of the stimuli and laminated 2D pictures of the target stimuli (see Table 3) for which the participants observed 20 visual stimuli (five opportunities across four stimuli). I selected 4 familiar categories, animals, musical instruments, home items, and food and included 10, 1-2 syllable stimuli from each category into sets (see Table 3). I included multiple exemplars that were systematically used for
pre- and post-intervention sessions (e.g. 5 different pictures of bok choy). Each set of stimuli (see Table 3) included 1 stimulus across the 4 stimuli categories.

**Dependent Variables**

The dependent variables I measured included the number of voluntary echoics emitted during the naming experiences, the degree of BiN, as defined by the percentage of correct, untaught listener and speaker responses to novel, familiar stimuli, and the percentage of non-arbitrary listener and speaker responses.

**Voluntary echoics.** Skinner (1957) defined echoics as “verbal behavior under the control of verbal stimuli [which], the response generates a sound-pattern similar to that of the stimulus.” (p. 55). I defined voluntary echoics as a response emitted immediately following the vocal antecedent delivered by the experimenter which held point-to-point correspondence with the antecedent. An example of a voluntary echoic was considered if the experimenter presented a 2D picture of bok choy and said “bok choy” and the participant said “bok choy” within 3 s of the presentation.

Independent responses were defined when the participant emitted the target auditory stimulus (e.g. “bok choy”) prior to the experimenter delivering the experience (“bok choy” with the presentation of the picture of bok choy). There was no criterion attached to the voluntary echoics or independent responses.

**Listener/speaker responses.** I defined the percentage of correct, untaught listener and speaker responses to novel, familiar stimuli using the same procedures as Experiment I. Criterion remained 75% accuracy across listener (UniN) and 75% across listener and speaker responses (BiN).
**Test for arbitrary relations.** Tests for arbitrary relations probes consisted of three response topographies: point (listener), intraverbal tact (speaker) and match (listener) responses for the following stimuli: animals, home items, musical instruments, and food. These categories were selected as familiar categories for which stimuli were chosen for naming experiences/probes. The first listener response consisted of the experimenter presenting a field of three stimuli from the naming experiences (see Appendix B1) and a vocal antecedent “point to ____”. I conducted 5 opportunities per category to respond as a listener, for a total of 20 opportunities. There was no consequence for correct or incorrect responses. The speaker response consisted of the experimenter presenting the visual antecedent (e.g. picture of rhubarb) and the vocal antecedent, “what category?” (see Appendix B2). I conducted 5 opportunities per category to respond as a speaker, for a total of 20 opportunities. No reinforcement or consequence was delivered for correct or incorrect responses. The final test for derived relations included a listener response to match stimuli within the same category (e.g. food). This consisted of the experimenter presenting a target stimulus (e.g. picture of cabbage) and a field of three stimuli (e.g. bok choy, ferret, kettle) and delivered the vocal antecedent “cabbage goes with ____” (see Appendix B3). I conducted 5 opportunities per category to respond as a listener, for a total of 20 opportunities. There was no consequence for correct or incorrect responses. Criterion for presence of arbitrary relations was considered 80% accuracy.

**Independent Variable: Successive Naming Experiences with Novel Stimuli (SNENS) across Two Temporal Proximity Conditions**

The independent variable was SNENS, defined as successive naming experiences with novel stimuli followed by single probe sessions for listener and speaker responses until mastery of transformation of stimulus function from listener to speaker, across two proximity conditions.
Condition A was defined as the simultaneous presentation of the visual stimulus (experimenter showed picture of bok choy) and the auditory stimulus (experimenter says “bok choy”). Condition B was defined as the delayed presentation of auditory stimuli (experimenter says “bok choy”) following presenting the visual stimulus (experiment showed picture of bok choy) for 1 s and another 1 s delay. Regardless of condition, each participant experienced a novel set of stimuli each session. At the onset of each session, I, or a second, independent observer selected a condition for each participant.

Each naming experience consisted of experimenters giving the participant 20 opportunities to observe the visual and auditory stimuli under one of the two aforementioned conditions. Two-hours following the experience I conducted listener (point-to) and speaker (label) probes using the same procedures described in Experiment I. The listener probes consisted of 2 opportunities to select the 4 target stimuli from a field of 3 (e.g. “point to bok choy”), for a total of 8 opportunities to respond as a listener. The speaker probes consisted of 2 opportunities to label the 4 target stimuli in a field of 1 (e.g. picture of bok choy), for a total of 8 opportunities to respond as a speaker.

Data Collection

I recorded the data using the same procedures described in the previous two experiments. During the experience and subsequent probe, I recording data using a pen and pre-made data sheet. I reported a correct or target response with a plus (+) and an incorrect or nontarget response with a minus (-). I recorded voluntary echoics as a total number of responses and I recorded listener and speaker responses as percentages.

Design
Experimenters employed an alternating treatments design to test the effects of proximity of visual and auditory stimuli on the emergence of BiN (Johnston & Pennypacker, 1993; Hains & Baer, 1989). Each session, participants randomly received naming experiences under one of the two conditions. I defined Condition A as the simultaneous condition, defined as the visual and auditory stimuli presented at the same time (e.g. experimenter holds up picture of bok choy).

Table 15

*Description of Independent Variable Temporal Proximity Conditions*

<table>
<thead>
<tr>
<th>Temporal Proximity Condition</th>
<th>Naming Experience &amp; IV</th>
<th>DV</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Simultaneous visual and auditory stimuli (Baseline condition)</td>
<td>Incidental tact experience-present picture and simultaneously provide name</td>
<td>• Percentage of correct listener and speaker responses</td>
</tr>
<tr>
<td></td>
<td>• L/S probes → 2 hours later</td>
<td>• # echoics emitted during experience</td>
</tr>
<tr>
<td>B Temporal delay between visual and auditory (present visual for 1 s, remove visual and within 1 s present auditory)</td>
<td>Incidental tact experience-present picture (1 s), remove picture then 1 s later provide name</td>
<td>• Percentage of correct listener and speaker responses</td>
</tr>
<tr>
<td></td>
<td>• L/S Probes → 2 hours later</td>
<td>• # echoics emitted during experience</td>
</tr>
</tbody>
</table>

and simultaneously says “bok choy”). Condition B was the delayed condition, defined as a one-second delay between presentation of the visual stimulus and the experimenter’s delivery of the auditory stimulus. At the onset of each session, I, or a second independent observer, selected from a bin of equal number of sheets of paper with “A” or “B” for all participants. This dictated the condition they received for that session (see Table 4). I conducted these procedures prior to each session. If a participant received four consecutive sessions of one condition, I rotated to the other condition for the fifth session.

**Procedures**
I collected data during the participant’s school day, typically one session conducted per school day. Data collection occurred during regularly scheduled instructional times. Given the time delay requirement, I presented the naming experience first thing following arrival to school. Prior to the onset of naming experiences, I conducted a brief probe to confirm that the participants did not know the names of the target stimuli. Incorrect or no response indicated novelty of the stimuli and I considered the stimuli for the naming experience. Once I identified novel, familiar stimuli, I conducted the naming experience. Each set of stimuli used across the naming experiences included one stimulus from the following four categories: animals, food, home items, and musical instruments (see Table 3).

At the start of each session, I or a second, independent observer, selected conditions from a basket of equal number of each condition. This dictated the participant’s condition for that particular session. Each participant received a random rotation (see Table 4) of all 10 sets of stimuli. If a participant received 4 consecutive sessions in the same condition, I manually switched the condition for the fifth session. Following ten repeated pairings and subsequent listener/speaker probes, I conducted tests of derived relations.

**Condition A (Simultaneous).** During the experience in the simultaneous condition, the experimenter used 2D laminated pictures of each target stimulus (see Table 3). The experimenter presented the target stimulus by gaining the participant’s attention, displaying the picture and simultaneously labeling the picture (e.g. “bok choy”). I presented each stimulus, 4 stimulus per set of stimuli, 5 times each for a total of 20 opportunities. During the experience, experimenters collected data on the number of voluntary echoes of the names of the target stimuli (e.g. experimenter said, “bok choy” and participant responded “boy choy”). Two-hours following a naming experience for a set of stimuli, I conducted listener (point-to) and speaker (label) probes.
The listener probes consisted of two opportunities to select the four target stimuli from a field of three (e.g. “point to bok choy”). The speaker probes consisted of two opportunities to label the four target stimuli in a field of one (e.g. “boy choy”).

**Condition B (Delay).** During the experience in the temporal delay condition, the experimenter used 2D laminated pictures of each target stimulus (see Table 3). The experimenter presented the target stimulus by gaining the participant’s attention, displaying the picture for 1 second, removing the picture for 1 s, and then labeling the picture (e.g. “bok choy”). I presented each stimulus, 4 stimulus per set of stimuli, 5 times each for a total of 20 opportunities. During the experience, experimenters collected data on the number of independent responses during the experience and voluntary echoics of the names of the target stimuli (e.g. experimenter said, “bok choy” and participant responded “boy choy”). Two-hours following a naming experience for a set of stimuli, I conducted listener (point-to) and speaker (label) probes. The listener probes consisted of two opportunities to select the four target stimuli from a field of three (e.g. “point to bok choy”). The speaker probes consisted of two opportunities to label the four target stimuli in a field of one (e.g. “boy choy”).

**Test for arbitrary relations.** Following ten naming experiences and subsequent probes, I conducted a test of arbitrary relations. This consisted of two listener responses and one speaker response to measure the degree of abstraction, or language relations, acquired following the naming experiences. I conducted the test for derived relations in the following order: point to (listener), tact (speaker), and speaker-to-listener match responses (listener). That is, the participant experienced 20 opportunities to point to categories (e.g. “point to animal”), 20 opportunities to tact categories (e.g. “what category”), followed by 20 opportunities to match
Table 16

*Experiment III Stimuli Sets*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kale</td>
<td>Fig</td>
<td>Cobbler</td>
<td>Cabbage</td>
<td>Crepe</td>
<td>Rhubarb</td>
<td>Bok Choy</td>
<td>Kazoo</td>
<td>Radish</td>
<td>Turnip</td>
<td>Collard</td>
</tr>
<tr>
<td>Zither</td>
<td>Tuba</td>
<td>Flute</td>
<td>Oboe</td>
<td>Organ</td>
<td>Vibes</td>
<td>Vibes</td>
<td>Harp</td>
<td>French Horn</td>
<td>Trombone</td>
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<tr>
<td>Possum</td>
<td>Puma</td>
<td>Boar</td>
<td>Gecko</td>
<td>Mantis</td>
<td>Ferret</td>
<td>Lemur</td>
<td>Locust</td>
<td>Eagle</td>
<td>Mealworm</td>
<td></td>
</tr>
<tr>
<td>Strainer</td>
<td>Tongs</td>
<td>Ladle</td>
<td>Chimes</td>
<td>Whisk</td>
<td>Kettle</td>
<td>Grater</td>
<td>Incense</td>
<td>Swiffer</td>
<td>Outlet</td>
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</tr>
</tbody>
</table>
Table 17

Order of Stimuli and Condition Presentation

<table>
<thead>
<tr>
<th>Set</th>
<th>Condition</th>
<th>Set</th>
<th>Condition</th>
<th>Set</th>
<th>Condition</th>
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<td>A</td>
<td>4</td>
<td>B</td>
<td>9</td>
<td>A</td>
</tr>
</tbody>
</table>

Note. I used a list randomizer (random.org) to counterbalance the presentation of sets across the participants regardless of condition. Prior to each session, experimenters selected conditions blindly, however, following four consecutive sessions of one condition, I manually selected the opposite condition.
from auditory (e.g. “cabbage goes with ____”) to visual (field of 3, one food item and two non-exemplars).

**Interobserver agreement (IOA)**

Across probe and intervention sessions, I collected data on the percentage of IOA using a second, independent observer. IOA was calculated using point-by-point procedures, dividing the total number of correct responses recorded by one observer (the lower of the two totals) by the total number of correct responses recorded by the other observer and multiplying the result by 100 percent. During naming experiences, I collected IOA for 22% of sessions with 99% agreement. During subsequent probes, I collected IOA on 37% of sessions with 99% agreement. IOA was collected for 16% of test for derived relation sessions with 100% agreement.

**Results**

Results from the current study are displayed in Figures 15-17. Figure 15 displays the voluntary echoics for each naming experience and Figure 16 displays the percentage of correct listener/speaker responses across the two proximity conditions. Results are discussed across participants by proximity conditions to describe the effects of the intervention on voluntary echoics and accuracy of listener/speaker responses. Each participant received a total of 10 naming experience and probe sessions.

Figure 15 displays the number of voluntary echoics emitted by each participant during each naming experience across proximity conditions. During naming experiences, participants received 20 opportunities to voluntarily echo target stimuli. Overall, participants reliably produced voluntary echoics during each naming experience, regardless of condition, with the exception of Participant E. During Condition A (simultaneous), participants emitted an average of 19 voluntary echoics during naming experiences. Participant B emitted 2 independent
response during Condition A naming experiences and Participant C emitted 1. The remaining participants emitted no independent responses during Condition A (simultaneous). During Condition B (delay), participants emitted an average of 17 voluntary echoics during naming experiences. During Condition B (delay) experiences, Participant A emitted independent responses during 4 of 5 experiences, with an average of 3 per naming experience. Participant B emitted independent responses during 4 of 6 experiences, with an average of 2 per naming experience. Participant C emitted no independent responses during Condition B (delay) naming experiences and Participants D and E emitted 1 independent response. Lastly, Participant F emitted an average of 3 independent responses across two naming experiences. Figure 16 displays the percentage of correct listener and speaker responses during each naming experience across the two proximity conditions. Across both conditions, participants reliably demonstrated UniN (greater than 75% accurate listener responses). Participants averaged 8 (93%) correct listener responses across Condition A (simultaneous) and 8 (95%) correct listener across Condition B (delay). During Condition A (simultaneous), participants emitted an average of 3 (33%) correct speaker responses and during Condition B (delay) an average of 3 (34%) accurate speaker responses.

Participant A emitted 8 (100%) accurate listener responses across Conditions A (simultaneous) and B (delay) and 3 (40%) accurate speaker across Condition A (simultaneous) and 5 (63%) accurate speaker responses across Condition B (delay). Across Condition A (simultaneous), Participant B emitted 7 (90%) accurate listener responses and 8 (100%) accurate listener responses across Condition B (delay). Participant B emitted 1 (15%) accurate speaker responses across Condition A (simultaneous) and 3 (45%) across Condition B (delay). Across Condition A (simultaneous), Participant C emitted 7 (88%) accurate listener responses and 8
Figure 14. Figure 14 displays the number of voluntary echoics, and independent responses emitted across the participants during Naming experiences for both simultaneous (A) and delay (B) conditions, as a stacked bar. The gray (delay) and black (simultaneous) bars indicate experimenter-defined echoic responses across the two conditions. The open (white) bars indicate independent responses. I defined independent responses as a correct tact emitted following the presentation of a visual stimulus prior to the experimenter’s presentation of the tact. I delivered 20 experiences during each session.
(93%) accurate listener responses across Condition B (delay). Participant C emitted 2 (29%) accurate speaker responses across Condition A (simultaneous) and 2 (28%) across Condition B. Participant D emitted 8 (100%) accurate listener responses across Conditions A (simultaneous) and B and 6 (72%) accurate speaker across Condition A (simultaneous) and 3 (39%) accurate speaker responses across Condition B (delay). Participant E emitted 7 (86%) accurate listener responses across Conditions A (simultaneous) and B (delay) and 1 (13%) accurate speaker across Conditions A (simultaneous) and B (delay). Across Condition A (simultaneous), Participant F emitted 8 (94%) accurate listener responses and 7 (86%) accurate listener responses across Condition B (delay). Participant F emitted 3 (31%) accurate speaker responses across Condition A (simultaneous) and 2 (21%) across Condition B (delay).

Figure 17 displays the percentage of correct responses across derived relation probe sessions. Test of derived relation probes were not conducted prior to onset of study. Participant A emitted 100% accurate listener responses, 80% accurate intraverbal tact responses, and 90% accurate speaker-to-listener match responses. Participant B emitted 85% accurate listener responses, no accurate intraverbal tact responses, and 50% accurate speaker-to-listener match responses. Participant C emitted 90% accurate listener responses, 20% accurate intraverbal tact responses, and 60% accurate speaker-to-listener match responses. Participant D emitted 100% accurate listener responses, 10% accurate intraverbal tact responses, and 70% accurate speaker-to-listener match responses. Participant E emitted 75% accurate listener responses, 15% accurate intraverbal tact responses, and 50% accurate speaker-to-listener match responses. Participant F emitted 100% accurate listener responses, 30% accurate intraverbal tact responses, and 70% accurate speaker-to-listener match responses.
Figure 15. Figure 15 displays the percentage of correct, untaught listener and speaker responses following each naming experience for both simultaneous (A) and delay (B) conditions. The open marks indicate listener responses across both conditions and the closed marks indicate speaker responses across both conditions. I provided each participant with 8 opportunities to point to (select) and tact (label) for each naming experience.
Discussion

Results of Experiment III did not show significant differences between the two temporal proximity conditions in accuracy of listener/speaker responses and these outcomes were consistent across the participants. However, in the absence of the storybook and the addition of consistent opportunities for voluntary echoic, there were some unexpected findings. With regards to accurate listener/speaker responses, all of the participants demonstrated reliable UniN as a function of SNENS regardless of temporal proximity condition. Transformation of stimulus function from listener to speaker responses occurred but did not reliably reach criterion-level across the participants (see Figure 16). It appears that the SNENS intervention functioned to condition observing familiar visual and auditory stimuli as reinforcers for listener responses, with some acquisition of bidirectional operants.

Compared to Experiments I and II, participants had reliable opportunities to echo target stimuli during each naming experience, regardless of condition. That is, there was no delay in presentation of auditory stimulus and participants opportunity to voluntarily echo the target auditory stimulus. As such, participants emitted increased echoic responses during successive novel naming experiences. During Condition A (simultaneous) naming experiences, participants echoed nearly all opportunities (20 opportunities provided per session). During Condition B (delay) naming experiences, participants also voluntarily responded to echoic opportunities; however, given the one second delay between presentation of visual and auditory stimuli, several of the participants emitted independent responses within the one second delay. That is, during the experience, the participants acquired the tact for the visual stimulus.

Participants with the strongest degree of BiN (Participants A and B) demonstrated increased accurate speaker responses during delayed conditions (Condition B) than during
**Figure 16.** Figure 16 displays arbitrary relational responding across listener (point to), speaker (tact), and speaker to listener (tact to point to) following naming experiences for stimuli categories. I did not conduct these assessments prior to intervention; however, during pre-intervention tacts participant either emitted no response or incorrect tacts. I defined listener responses as correct selection of stimuli in a field of three, given a vocal antecedent (e.g. point to the animal”). I defined a speaker response as the correct tact of the category of stimuli given a vocal antecedent (e.g. “what category does this belong with?”). I defined speaker to listener responses if given a vocal antecedent, e.g. “Zither goes with…” and the participant correctly identified another musical instrument given a field of three stimuli.
simultaneous conditions (Condition A). Participants C and D demonstrated joining of listener and speaker during one naming probe within each condition; however, the data did not remain consistent on the subsequent novel naming experience. Regarding the delayed condition, it may be that the delayed delivery of the “name” may have increased the motivating operation for the “need to know the name” of the visual stimulus. Recent findings on joint attention suggested that tact opportunities had strongest outcomes for joint attention (Harms, 2019).

Interestingly, using SNENS lead to unanticipated findings that experimenters did not control for at the onset of the study. During naming probes, or assessments of accurate listener/speaker responses, few of the participants, in the absence of a correct tact (e.g. “oboe”) attempted to produce vocal responses that correspond to the target response (e.g. “instrument”). That is, the participants could go from component to category in the absence of training. Following the intervention, I assessed for listener/speaker responses across the categories used naming stimuli. Participants instructional history included sorting categories; however, instructional programs had not yet targeted point to or tact categories. All of the participants demonstrated criterion-level listener responses (>80% accuracy), which consisted of a point-to response. Participants emitted at least 50% accurate responses for speaker-to-listener responses. Lastly, participant emitted few or no correct responses for intraverbal tact responses, with the exception of Participant A. These findings support previous research on the relations between the degrees of BiN and other language relations (Frank, 2018; Morgan, 2018).

There were some limitations to address. First, in using an alternating treatment design, I could not control for sequence effect. That is, in conducting successive novel naming experiences, I could not control for learning occurring as a function of repeated measures. Previous literature on BiN suggest that successive novel naming experiences lead to joining of
listener and speaker responses (Kleinert, 2018; Lo, 2016). This must be considered in examining results of Experiment III; regardless, there were no consistent differences across the two conditions. Future studies should increase the delay between presentation of visual and auditory stimuli (e.g. five s) to test if increasing the delay results in more apparent differences in accurate listener/speaker responses. Despite the limitations, the serendipitous findings of derived relations warranted continued research.

**Rationale for Experiment IV**

These findings of Experiment III suggested a relation may exist between accuracy of listener and speaker responses and other bidirectional relations (Frank, 2018; Morgan, 2018). Further, these findings suggest that certain relations emerge within the “continuum” of BiN. That is, all of the participants demonstrated reliable UniN and could derive component to category responses. Participant A demonstrated strong degrees of BiN and was the only participant to meet criterion across all three derived relation responses. Recently, researchers have tested the effects of BiN on other bidirectional relations and found that stronger degrees of BiN result in derivation of other relations (Frank; 2018; Morgan, 2018). Frank (2018) found that levels of proficiency on tests of basic concepts was significantly related to the participant’s “level” or degree of BiN. Further, Morgan (2018) found that arbitrarily applicable relations occurred with greater accuracy following acquisition of BiN for unfamiliar stimuli (e.g. symbols). These findings lead to research questions related to where on the “continuum” of BiN these relations emerge. Experiment III served as a pilot study for Experiment IV. The purpose of Experiment IV was to control for the design limitation and experientially control for the serendipitous findings of Experiment III, by directly replicating the procedures of Morgan (2018) as a single-case experimental design.
Research Questions for Experiment IV

1. Is there a functional relation between accuracy of untrained listener and speaker responses (degree of BiN) and other arbitrarily applicable listener and speaker responses (AAR)?
Chapter V

EXPERIMENT IV: FUNCTIONAL RELATION BETWEEN ACCURACY OF UNTRAINED LISTENER AND SPEAKER RESPONSES (DEGREES OF BIN) AND THE EMERGENCE OF OTHER DERIVED LISTENER AND SPEAKER RELATIONS

Method

Participants

Participants included six students who attended a CABAS® (Comprehensive Application of Applied Behavior Analysis to Schooling) accredited preschool located outside a metropolitan area in the Eastern United States. In this setting, applied behavior analytic practices were systematically implemented across all instruction. Their verbal repertoires were assessed using the *CABAS International Curriculum and Inventory of Repertoires for Children from Preschool through Kindergarten* (C-PIRK®; Greer, 2014). All of the students were enrolled in either an integrated Early Intervention (EI) classroom, integrated preschool classroom with a ratio of 16 students, one teacher, and two teaching assistants, or a self-contained preschool classroom with a ratio of 12 students, one teacher, and two teaching assistants. They ranged in age from 22 to 40 months old at the onset of the study. Two of the participants were neurotypically developing and four were classified with Individualized Education Plans (IEP). One of the participants, Participant C, was bilingual in American English and Spanish and the remaining participants were monolingual American English-speakers.

All of the participant demonstrated the presence of UniN at the onset of the study, and four of the participants had participated in previous studies included herein. At the onset of the study, I selected the participants as they demonstrated relevant prerequisites for the establishment of BiN: conditioned reinforcement for observing voices, conditioned
reinforcement for observing 2D stimuli, conditioned reinforcement for observing 3D stimuli, point topography, and independent mands and tacts. None of the participants had demonstrated BiN prior to the onset of the study with the criterion of 80% accurate point, tact, and intraverbal responses for a novel set of stimuli (Greer et al., 2005; Kleinert, 2018; Morgan, 2018). All of the participants functioned on a listener/speaker level of verbal behavior. At the onset of the study the participants demonstrated basic category training as a listener (e.g. sorting), as dictated by the C-PIRK®; however, had not received direct training for responding to categories as an intraverbal response. See Table 18 for a description of participant characteristics.

Table 18

*Description of Participants*

<table>
<thead>
<tr>
<th>Participants</th>
<th>Age (Months)</th>
<th>Gender</th>
<th>Grade</th>
<th>Classification</th>
<th>Common Cusps and Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.3 (40)</td>
<td>M</td>
<td>Preschool</td>
<td>IEP</td>
<td>Teacher presence results in instructional control, Independent Tacts, Conditioned Reinforcement for Adults Faces/Voices, Listener Literacy, Conditioned Reinforcement for 2D, Generalized Visual MTS, Unidirectional Naming (UniN)</td>
</tr>
<tr>
<td>B</td>
<td>3.3 (39)</td>
<td>M</td>
<td>Preschool</td>
<td>IEP</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3.2 (38)</td>
<td>F</td>
<td>Preschool</td>
<td>IEP</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3.2 (38)</td>
<td>F</td>
<td>Preschool</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1.8 (22)</td>
<td>M</td>
<td>Early Intervention</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3.1 (37)</td>
<td>F</td>
<td>Preschool Special Class (12:1:2)</td>
<td>IEP</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Relevant cusps/capabilities were common among all participants and were required as inclusion criterion for study participation. Participants B, C, and D participated in Experiment III.
Setting and Materials

I conducted both the dependent measures (listener training and tests for derived speaker responses) and intervention sessions (BiN probes) in the same setting as was described in Experiment III. Materials used were a laptop computer, to present training and assessment stimuli, pre-made data sheets, and pens. Tables 27 and 28 describe the stimuli used for BiN experiences and subsequent probes. Tables 19 and 21 describe the stimuli used for derived relation training and assessment. Materials used for derived relational response training and derived speaker probes were identical to those used in Morgan (2018).

Dependent Variables

The dependent variables measured in this study were the degree of arbitrary derived listener and speaker relations, defined (a) by the percentage of correct, untaught speaker responses following $A \rightarrow B$ training and (b) by the percentage of correct, untaught listener and speaker responses following $A \rightarrow B$ and $A \rightarrow C$ training, and the degree of BiN for novel, familiar stimuli, defined by the percentage of correct untaught listener and speaker responses following an incidental naming experience. These dependent variables were directly replicated from Morgan (2018).

The first measure of arbitrary relational responses was measured by 20 speaker responses for mutually entailed relations. The subsequent measures of arbitrary derived relations were measured by 20 responses (10 listener and 10 speaker) for mutually entailed relations and 18 speaker responses for combinatory entailment. Tables 26 and 28 show descriptions of the responses required for arbitrary listener and speaker derived relations. The degree of BiN was measured by 10 listener responses (point to), 10 speaker responses (tact), and 10 speaker responses (intraverbal). Criterion for demonstration of the three dependent variables was
considered 80% accuracy across one probe, with the added criterion of 80% across one novel probe for demonstration of the presence of BiN. Table 19 shows an overview of all relations taught and trained across training and assessment phases of the dependent variable.

**Independent Variable: Establishment of BiN**

The independent variable was the establishment of BiN for novel, familiar stimuli. The establishment of BiN was considered 80% accuracy across listener (point to) and speaker (tact and intraverbal) across two consecutive sets of novel stimuli. To establish BiN, I used two procedures, (a) Successive Naming Experience with Novel Stimuli (SNENS) followed by single probe sessions for listener and speaker responses, which was then followed by a novel naming experience and single probe for listener and speaker responses. This was the same procedure utilized in Experiment III. The other intervention included Single Naming Experiences with Repeated Probe sessions (SNERP) until mastery of transformation of stimulus function from listener to speaker. All participants began with SNENS to induce BiN; however, if speaker data decreased to 0 or overall did not increase following 5 sessions or remained a 0 for 3 sessions, I implemented SNERP.

**SNENS.** The independent variable was SNENS defined as successive naming experiences with novel stimuli followed by single probe sessions for listener and speaker responses until mastery of transformation of stimulus function from listener to speaker, using incidental naming experiences (Hranchuk et al., 2018; Kleinert, 2016) for novel, familiar stimuli. Each naming experience consisted of experimenters delivering 20 opportunities for the participant to observe the visual and auditory stimuli using incidental naming experiences. These procedures were identical to the procedures of Condition A (simultaneous) in Experiment III.
**Table 19**

**Description of Stimulus Class for Experiment IV**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Name (A)</th>
<th>Picture (B)</th>
<th>Stimulus Class (Phase 3) (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insect</td>
<td><img src="image1" alt="Insect Image" /></td>
<td>Int</td>
</tr>
<tr>
<td></td>
<td>Feline</td>
<td><img src="image2" alt="Feline Image" /></td>
<td>Ver</td>
</tr>
<tr>
<td>2</td>
<td>Serpent</td>
<td><img src="image3" alt="Serpent Image" /></td>
<td>Ver</td>
</tr>
<tr>
<td></td>
<td>Mollusk</td>
<td><img src="image4" alt="Mollusk Image" /></td>
<td>Int</td>
</tr>
</tbody>
</table>

*Note. All names trained were no more than 2 syllables. Ver was the experimentally contrived replacement for vertebrate and int was the replacement for invertebrate, as done in Morgan (2018).*

**Table 20**

**Description of Training and Assessment Sequence for Arbitrary Relations**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Trained Relations</th>
<th>Untaught Relations Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A → B</td>
<td>B → A</td>
</tr>
<tr>
<td></td>
<td>A → B</td>
<td>B → A</td>
</tr>
<tr>
<td>2</td>
<td>A → B</td>
<td>B → A</td>
</tr>
<tr>
<td>3</td>
<td>B1 → B2</td>
<td>C → B</td>
</tr>
<tr>
<td></td>
<td>C → A1A2</td>
<td>B → C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B1B2 → C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B2 → B1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A → C</td>
</tr>
</tbody>
</table>

*Note. The numbers refer to phase in which stimuli were trained, as done in Morgan (2018).*
Two-hours following the experience, I conducted listener (point-to) and speaker (tact and intraverbal tact) probes using the same procedures described in the previous studies. The listener probes consisted of two opportunities to select the 5 target stimuli from a field of three (e.g. “point to tinker”), for a total of 10 opportunities to respond as a listener. The tact probe consisted of two opportunities to label the 5 target stimuli in a field of one (e.g. picture of tinker toy), for a total of 10 opportunities to respond as a speaker. The intraverbal probe consisted of two opportunities to label the 5 target stimuli in a field of one (e.g. picture of a tinker toy) give the vocal antecedent, “what is this?” for a total of 10 opportunities to respond as a speaker. The experimenter conducted a post-intervention probe novel once the participants demonstrated 60% accurate speaker responses, 80% accurate speaker responses, and 100% accurate speaker responses, respectively. The establishment of BiN was considered when the participant demonstrated 80% accuracy across listener and speaker for two novel sets of stimuli.

SNERP. The second independent variable was SNERP, defined as single naming experiences with repeated probe sessions until mastery of transformation of stimulus function for stimuli in the single set, using incidental naming experiences (Hranchuk et al., 2018; Kleinert, 2016) for novel, familiar stimuli. Each naming experience consisted of experimenters delivering 20 opportunities for the participant to observe the visual and auditory stimuli using incidental naming experiences. These procedures were identical to the procedures described above for SNENS. Two-hours following the experience, I conducted listener (point-to) and speaker (tact and intraverbal tact) probes using the same procedures described in all previous experiments. The listener probes consisted of two opportunities to select the 5 target stimuli from a field of three (e.g. “point to tinker”), for a total of 10 opportunities to respond as a listener. The tact probe consisted of two opportunities to label the 5 target stimuli in a field of one (e.g. picture of
tinker toy), for a total of 10 opportunities to respond as a speaker. The intraverbal probe consisted of two opportunities to label the 5 target stimuli in a field of one (e.g. picture of a tinker toy) give the vocal antecedent, “what is this?”, for a total of 10 opportunities to respond as a speaker. Successive sessions consisted of only point, tact, and intraverbal tact for the single set until mastery (80%). The experimenter conducted a post-intervention probe novel once the participants demonstrated 80% accurate speaker responses. The establishment of BiN was considered when the participant demonstrated 80% accuracy across listener and speaker for a novel set of stimuli.

**Data Collection**

Data during naming experiences on voluntary echoics and listener/speaker responses were collected using the same procedures described in Experiment III. During training sessions for the dependent variable, correct responses were recorded with a plus (+) and reinforcement was delivered and during assessment sessions for the dependent variable, correct responses were also recorded with a plus (+), but no reinforcement was delivered. Following an incorrect response during training phases, a minus (-) was recorded along with a correction procedure (Tables 21 and 25) and during assessment sessions, a minus (-) was recorded; however, no correction procedure was presented.

**Design**

The design of the study was a multiple probe design across participants (Horner & Baer, 1978; see Figure 17). The procedure consisted of (1) pretest of all experimental responses across the dependent and independent variable to ensure the participants did not have the experimental responses in repertoire, (2) pre-experimental training phases to establish an instructional history for point to and tact categories for novel stimuli, (3) Derived Relation Listener Training Phase 1,
Figure 17. Figure 17 displays the sequence of the experimental design for Experiment IV. I used a multiple probe design across participants to test if emergence of BiN using successive novel naming experiences functioned to increase derived relational responses.
(4) Derived Relation Test for speaker responses across two consecutive sessions, (5) Derived Relation Listener Training Phase 2, (6) Derived Relation Test for speaker responses across two consecutive sessions, (7) Derived Relation Listener Training Phase 3, (8) Derived Relation Test for speaker responses across two consecutive sessions, (9) SNENS (criterion= >60% or 6/10 for speaker responses) or SNERP if speaker data did not increase, (10) Derived Relation Test for speaker responses for Phases 1, 2, and 3 (criterion= 80% accurate responses), (11) continued SNENS or SNERP (criterion= >80% or 8/10 for speaker responses), and (12) Derived Relation Test for speaker responses for Phases 1, 2, and 3 (criterion= 80% accurate responses). This sequence continued until participants demonstrated 80% accurate derived speaker responses, 80% across two novel sets of intervention in a single session or did not demonstrate BiN or increased derived speaker responses following 15 phases of intervention. Figure 17 shows the full sequence of the study.

**Procedures: Simple-to-Complex (STC) Protocol**

Pre- and post-intervention procedures for derived relation training and test phases were directly replicated from Morgan (2018), with the exception of pre-experimental intraverbal tact training. We used a simple-to-complex (STC) protocol in which we interspersed training phases and testing phases in a predetermined order such that each derived relations probe was conducted only after prerequisite training had been mastered (Buffington, Fields, & Adams, 1997; Fields, Reeve, Rosen, Verelas, Adams, Belanich, & Hobbie, 1997; Fienup, Wright, & Fields, 2015). Research has shown that prior training of component skills can enhance “the likelihood of equivalence class formation” (Buffington et al., 1997, p. 71).

**Pre-experimental intraverbal tact training.** Prior to the onset of the experiment, I conducted instruction of category training to establish an instructional history for categorization.
of novel, familiar stimuli. This included intraverbal tact responses for the following categories: musical instruments, cartoon characters, home items, and transportation. These categories did not appear in subsequent derived relational responding training/probes or BiN probes. For each session, the participant received 5 opportunities to respond to the four categories, for a total of 20 opportunities. During each session, the participant was seated across from the experimenter with the stimuli (e.g. laptop) placed on the table between them. The experimenter presented the visual stimulus (e.g. garbage truck), provided the vocal antecedent, “what category?”, and the participant was given three s to respond. If the participant emitted the target vocal response (e.g. “transportation”), the response was recorded as correct, and the experimenter delivered reinforcement. If the participant emitted no response or an incorrect response within three s, the experimenter implemented a correction procedure. This consisted of the experimenter providing the correct response (e.g. “transportation”) and providing the participant an opportunity to independently emit the correct response. The experimenter provided up to three opportunities for independent responses, prior to proceeding to the subsequent learn unit. Criterion for mastery of pre-experimental intraverbal tract training was considered 90% across two consecutive sessions or 100% across one session. Once participants demonstrated mastery criterion, they were considered candidates for entering intervention. Participants B, C, and D were included in Experiment III and demonstrated greater than 80% emergent categorization as measured by listener responses (point to) and did not receive pre-experimental listener training.

Figure 18 displays the number of correct responses for listener (point to) and speaker (intraverbal tact) across 4 common categories. Participant A mastered point and tact categories in two sessions. Participant B demonstrated mastery following 8 sessions and Participant C mastered the prerequisites in 3 sessions. Participant D demonstrated mastery following 3
Figure 18. Figure 18 displays the number of correct responses to listener and speaker responses during pre-intervention training for categories (cartoon, transportation, home items, and instrument). Participants B, C, and D received listener opportunities during Experiment III.
sessions, while Participant E acquired listener responses in 4 sessions and intraverbal tact responses following 5 sessions. Participant F acquired listener responses following 5 sessions and speaker responses following 3 sessions.

**Listener training (phase 1).** Listener training required the participant to identify a target stimulus, using a selection (point to) response. This training phase consisted of two experimentally defined stimulus class, using animals (e.g. feline and insect). During each session, participants received 10 opportunities to point to each stimulus class for a total of 20 opportunities. Training sessions were conducted using Single Exemplar Instruction (SEI) in which 1 exemplar of each stimulus with a defined stimulus class was presented (see Table 23 for exemplars of stimuli used in listener training). Mastery criterion was considered 90% accuracy across two consecutive sessions or 100% accuracy across one session, with a minimum of two sessions required (Morgan, 2018).

During each session, the participant was seated across from the experimenter with the stimuli (e.g. laptop) placed on the table between them. The experimenter presented a PowerPoint slide with three stimuli on it, one target exemplar and two non-target exemplars. One of the non-target stimuli was from the other stimulus class targeting for training and the other was a visual stimulus not targeted during any intervention phases (e.g. fish). After presenting the stimuli, experimenters presented the vocal antecedent (e.g. “point to feline”) and provided the participant 5 s to respond. If the participant emitted the target selection response (e.g. points to the lion), the response was recorded as correct, and the experimenter delivered reinforcement. If the participant emitted no response or an incorrect response within 5 s, the experimenter implemented a correction procedure. This consisted of the experimenter providing the correct response (e.g. pointing to feline) and providing the participant an opportunity to independently
emit the correct response. The experimenter provided up to three opportunities for independent responses, prior to proceeding to the subsequent learn unit. Criterion for mastery of listener training phase 1 was considered 90% across two consecutive sessions or 100% across one session. Trends in data were analyzed using the CABAS® Decision Protocol (Keohane & Greer, 2005). Table 23 provides a brief overview of decisions made within phases, including decisions to continue training, mastery criterion achieved, or stop decision.

Table 21
Exemplars of Stimuli used for Listener Training and Derived Relation Tests for Phases 1 and 2

<table>
<thead>
<tr>
<th>Phase 1 (Feline and Insect)</th>
<th>Phase 1 (Serpent and Mollusk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lion</td>
<td>Coral Snake</td>
</tr>
<tr>
<td>Panther</td>
<td>Scarlet King Snake</td>
</tr>
<tr>
<td>House Cat</td>
<td>Boa Constrictor</td>
</tr>
<tr>
<td>Bobcat</td>
<td>Python</td>
</tr>
<tr>
<td>Cougar</td>
<td>Garden Snake</td>
</tr>
<tr>
<td>Tiger</td>
<td>King Cobra</td>
</tr>
<tr>
<td>Fly</td>
<td>Any</td>
</tr>
<tr>
<td>Ladybug</td>
<td>Snail</td>
</tr>
<tr>
<td>Beetle</td>
<td>Oyster</td>
</tr>
<tr>
<td>Dragonfly</td>
<td>Clam</td>
</tr>
<tr>
<td>Grasshopper</td>
<td>Scallop</td>
</tr>
<tr>
<td>Wasp</td>
<td>Mussel</td>
</tr>
</tbody>
</table>

Note. These stimuli were replicated from Morgan (2018). Multiple visual exemplars of each stimulus were rotated across listener training learn units and derived relation assessments.

Derived relation test for speaker responses (phase 1). Phase 1 probe sessions consisted of assessing participants on responses to mutually entailed frames of coordination (Morgan, 2018). Mutual entailment responses consisted of intraverbal tacts for stimulus classes targeted during listener training, demonstrating emergence of B → A relations. For each session participants received 10 opportunities to respond to each stimulus class for a total of 20 opportunities. Assessments for derived relations were conducted using probe trials for which no
consequence was delivered. During each session, the participant was seated across from the experimenter with the stimuli (e.g. laptop) placed on the table between them. The experimenter presented a PowerPoint slide which contained one visual stimulus. Once experimenter gained the attention of the participants, the experimenters delivered the vocal antecedent, “what is this?” or Table 22

**Learn Unit Example for Listener Training for Phases 1 and 2**

<table>
<thead>
<tr>
<th>Antecedent</th>
<th>Behavior</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Point to the insect”</td>
<td><em>Correct response:</em> Pointing to the exemplar of an insect</td>
<td>Reinforcement in the form of generalized reinforcers (e.g. tokens, edibles)</td>
</tr>
<tr>
<td>![Insect Images]</td>
<td><em>Incorrect response:</em> No response or pointing to a non-exemplar</td>
<td>Correction procedure which consisted of the experimenter demonstrating the correct response and giving the participant an opportunity to independently respond.</td>
</tr>
</tbody>
</table>

**Note.** These stimuli were replicated from Morgan (2018). Each learn unit presentation consisted of a rotation of exemplars of stimulus within each animal class as shown in Table 21. For example, learn units for “insect” consisted of a different exemplar of an insect, any two nonexemplars (e.g. one serpent and one fish).

Table 23

**Description of Decision Protocol used for Training Sessions**

<table>
<thead>
<tr>
<th>Decision Opportunity</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three ascending data paths or five variably ascending data paths</td>
<td>Continue the training under the current short-term objective</td>
</tr>
<tr>
<td>Criterion achieved</td>
<td>Stop training and move to next assessment or subsequent short-term objective</td>
</tr>
<tr>
<td>Three descending data paths or five variably descending data paths or two sessions with 0% accuracy</td>
<td>Stop training sessions</td>
</tr>
</tbody>
</table>
“what category?” and provided 5 s for the participants to respond. Given the target intraverbal tact (e.g. “feline” or “insect”), experimenters recorded a correct response. No response or an incorrect intraverbal tact resulted in the experimenter recording a minus (-). Criterion for demonstration of mutually entailed responses was 80% accuracy across one session. Each test was conducted twice to ensure no learning occurred in the absence of intervention. If data increased, suggesting increased demonstration of mutual entailment, experimenters conducted a third pre-intervention probes. This was conducted until no learning occurred or accuracy of data remained stable or decreased.

**Listener training (phase 2).** Listener training for phase 2 consisted of training two additional stimulus classes (e.g. serpent and mollusk). The behavioral definition and procedures were conducted using the same methods explained in phase 1.

**Derived relation test for speaker responses (phase 2).** I conducted this assessment using the same methods described for phase 1 for serpent and mollusk.

![Legend: Trained Relations - Untrained Relations]

“Insect”

*Figure 19. Example of relations trained and assessed across Phases 1 and 2.*

**Listener training (phase 3).** In this phase, I taught participants to conditionally relate a stimulus from Phase 1 to a stimulus in Phase 2, under a new arbitrary stimulus class. Feline and serpent were trained as “ver” which was an experimentally defined replacement tact to define
“vertebrate”. Insect and mollusk were trained as “int” which was experimentally defined replacement tact to define “invertebrate”. During each training session, participants received 10 opportunities to respond to each arbitrary stimulus class, for a total of 20 opportunities. During each session, the participant was seated across from the experimenter with the stimuli (e.g. laptop) placed on the table between them. The experimenter presented a PowerPoint slide which contained a field of four stimuli, one target stimuli and three stimuli lining the bottom of the screen. One nontarget stimulus was from the other arbitrary stimulus class (e.g. mollusk) and the second nontarget stimulus was not included in intervention (e.g. bird). After gaining the participants attention toward the screen, the experimenter pointed to the target stimulus and provided the vocal antecedent, “felines are ver, can you find another animal that is ver?” and gave the participants 5 s to emit a match response.

If the participant emitted the target match response (e.g. matches serpent with feline), the response was recorded as correct, and the experimenter delivered reinforcement. If the participant emitted no response or an incorrect response within 5 s, the experimenter

<table>
<thead>
<tr>
<th>Antecedent</th>
<th>Behavior</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>“What category?”</td>
<td>Correct response: Saying the target class of animal presented (e.g. “insect”)</td>
<td>N/A</td>
</tr>
<tr>
<td>“What is this?”</td>
<td>Incorrect response: No response or saying a non-exemplar animal class</td>
<td>N/A</td>
</tr>
</tbody>
</table>

_Description of Probe Trial for Derived Relation Test Phases 1 and 2_

During each training session, participants received 10 opportunities to respond to each arbitrary stimulus class, for a total of 20 opportunities. During each session, the participant was seated across from the experimenter with the stimuli (e.g. laptop) placed on the table between them. The experimenter presented a PowerPoint slide which contained a field of four stimuli, one target stimuli and three stimuli lining the bottom of the screen. One nontarget stimulus was from the other arbitrary stimulus class (e.g. mollusk) and the second nontarget stimulus was not included in intervention (e.g. bird). After gaining the participants attention toward the screen, the experimenter pointed to the target stimulus and provided the vocal antecedent, “felines are ver, can you find another animal that is ver?” and gave the participants 5 s to emit a match response.

If the participant emitted the target match response (e.g. matches serpent with feline), the response was recorded as correct, and the experimenter delivered reinforcement. If the participant emitted no response or an incorrect response within 5 s, the experimenter
implemented a correction procedure. This procedure was consistent with the description provided in phase 1. Criterion for mastery of listener training phase 1 was considered 90% across two consecutive sessions or 100% across one session. Trends in data were analyzed using the CABAS® Decision Protocol (Keohane & Greer, 2005). Table 23 provides a brief overview of decisions made within phases, including decisions to continue training, mastery criterion achieved, or stop decision.

Derived relation test for listener and speaker responses (phase 3). During phase 3 derived relation test for listener and speaker responses, I assessed participants for mutual entailment and combinatorial entailment frames of coordination.

Mutually entailed listener and speaker responses (phase 3). Tests for acquisition of mutually entailed frames of coordination consisted of point and intraverbal tact responses demonstrating B → A and C→A relations. I provided 10 opportunities for participants to respond to each stimulus class as a listener and 10 for intraverbal tact, for a total of 20 opportunities. No consequence was delivered for correct or incorrect responses for either point or tact responses. Criterion for presence of mutually entailed frames of coordination was considered 80% correct responding across one session.

During each session, the participant was seated across from the experimenter with the stimuli (e.g. laptop) placed on the table between them. The experimenter presented a PowerPoint slide which contained a field of three stimuli, one target stimuli and two non-target stimuli. One nontarget stimulus was from the other arbitrary stimulus class (e.g. mollusk) and the second nontarget stimulus was not included in intervention (e.g. bird). After gaining the participants attention toward the screen, the experimenter pointed to the target stimulus and provided the
vocal antecedent, “point to ver”, and gave the participant 5 s to emit a response. Following 10 opportunities to point to the two arbitrary stimulus classes (ver and int), experimenters presented 10 opportunities for participants to respond as a speaker. Procedures were identical to the point to response; however, the slide contained one target exemplar (e.g. lion). Following presentation of the visual stimulus, the experimenter delivered the vocal antecedent, “felines are ____”, and gave the participant 5 s to tact the arbitrary stimulus class.

Table 25

*Learn Unit Example for Listener Training Phase 3*

<table>
<thead>
<tr>
<th>Antecedent</th>
<th>Behavior</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>“This is int, can you point to another int.”</td>
<td><em>Correct response:</em> Pointing to the picture of the animal that is in the “int” class (e.g. bee)</td>
<td>Reinforcement in the form of praise or playful physical contact (e.g. tickles)</td>
</tr>
</tbody>
</table>

| Incorrect response: No response or pointing to a non-exemplar (animal that does not correspond) | Correction procedure which consisted of the experimenter demonstrating the correct response and giving the participant an opportunity to independently respond. |

**Combinatorially entailed speaker responses (phase 3).** Tests for acquisition of combinatorially entailed speaker responses, which was comprised of combined frames of coordination and hierarchical frames, consisted of a series of intraverbal responses demonstrating $C \rightarrow B$ and $B \rightarrow C$ relations. I provided a total of 18 response opportunities during this session. This consisted of 14 intraverbal tact responses and 4 intraverbal responses. No consequence was delivered for correct or incorrect responses for either point or tact responses. Criterion for
presence of combinatorial entailment frames of coordination was considered 80% correct responding across one session.

Table 26

*Description of Assessed Responses for Derived Relation Test Phase 3*

<table>
<thead>
<tr>
<th>Antecedent</th>
<th>Behavior</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Point to int”</td>
<td><strong>Correct:</strong> Pointing to the corresponding visual stimuli</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td><strong>Incorrect:</strong> No response or pointing to a non-exemplar</td>
<td></td>
</tr>
<tr>
<td>“Insects are ____”</td>
<td><strong>Correct:</strong> Saying the name of the class of the given animal (e.g. ver)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td><strong>Incorrect:</strong> No response or saying the wrong class</td>
<td></td>
</tr>
<tr>
<td>“What category?  “Why are these the same?”</td>
<td><strong>Correct:</strong> Saying the name of the class both stimuli are in (e.g. int)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td><strong>Incorrect:</strong> No response or saying the wrong class</td>
<td></td>
</tr>
<tr>
<td>“This is int, can you tell me the name of another int?”</td>
<td><strong>Correct:</strong> Saying the animal class which is in the class of int (e.g. mollusk)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td><strong>Incorrect:</strong> No response or saying the name of the wrong animal class (e.g. feline)</td>
<td></td>
</tr>
<tr>
<td>“This is int, can you tell me the name of another int?”</td>
<td><strong>Correct:</strong> Saying the animal class which is in the class of int (e.g. mollusk)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td><strong>Incorrect:</strong> No response or saying the name of the wrong animal class (e.g. feline)</td>
<td></td>
</tr>
</tbody>
</table>
During each the first intraverbal tact response, the participant was seated across from the experimenter with the stimuli (e.g. laptop) placed on the table between them. This setting remained consistent across all tests for combinatorial entailment responses. The experimenter presented a PowerPoint slide which contained 2 stimuli within a given arbitrary stimulus class (e.g. serpent and feline), gained the participant’s attention, and delivered the vocal antecedent, “what are these?” A correct response was defined as the participant emitting the correct arbitrary stimulus class (e.g. “ver”) within 5 s and an incorrect response was defined as the participant emitting an incorrect arbitrary stimulus class (e.g. “int”), no response, or a non-target response (e.g. “feline”).

During the second intraverbal tact response, the experimenter presented a PowerPoint slide which contained 1 stimulus (e.g. a feline), gained the participants attention, and delivered the vocal antecedent, “can you name an animal that is like this one?” A correct response was defined as the participant emitting the correct stimulus class (e.g. “serpent”) within 5 s and an
incorrect response was defined as the participant emitting an incorrect stimulus class (e.g. “mollusk”), no response, or a non-target response (e.g. “feline”). Experimenter provided a total of four responses opportunities, one per arbitrary stimulus class. The third intraverbal responses consisted of the same procedures as the second intraverbal response, in the absence of a visual stimulus. The experimenter gained the participants attention and delivered the vocal antecedent, “mollusks are int, can you tell me the name of another animal that is int?” for a total of four response opportunities, one per arbitrary stimulus class.

**Naming experience (incidental tact experience).** Each naming experience consisted of experimenters giving the participant 20 opportunities to observe the visual and auditory stimuli using incidental naming experiences. These procedures were identical to the procedures of Condition A (simultaneous) in Experiment III. At the onset of each session, the experimenter provided the participant with a novel set of 5 familiar stimuli, one stimulus across each of the following categories: tools, toys, food, flowers, and gems. Familiar stimuli were defined as stimuli that participants may encounter within their environment; however, had not received direct training on the names of the stimuli. Each set of stimuli consisted of one and two-syllable words, with each set containing one, one-syllable word. If a set contained a combined word (e.g. eggplant), I included a second one-syllable stimulus.

During each session, participants sat across from the experimenter at child sized tables with a laptop between them. The experimenter presented a series of PowerPoint slides, each containing one visual stimulus. The experimenter gained the attention of the participant, pointed to the visual stimuli and delivered the experience (e.g. “fressia”). This was conducted 4 times.
### Table 27

**Stimuli Sets for Experiment IV**

<table>
<thead>
<tr>
<th>Set</th>
<th>Tools</th>
<th>Toys</th>
<th>Food</th>
<th>Flowers</th>
<th>Gems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crombie</td>
<td>Rubiks</td>
<td>Mochi</td>
<td>Tulip</td>
<td>Jade</td>
</tr>
<tr>
<td>2</td>
<td>All</td>
<td>Gameboy</td>
<td>Quinoa</td>
<td>Lily</td>
<td>Garnet</td>
</tr>
<tr>
<td>3</td>
<td>Plane</td>
<td>Slingshot</td>
<td>Quince</td>
<td>Poppy</td>
<td>Opal</td>
</tr>
<tr>
<td>4</td>
<td>Bolt</td>
<td>Keychain</td>
<td>Coleslaw</td>
<td>Orchid</td>
<td>Quartz</td>
</tr>
<tr>
<td>5</td>
<td>Level</td>
<td>Jacks</td>
<td>Parsley</td>
<td>Daisy</td>
<td>Sapphire</td>
</tr>
<tr>
<td>6</td>
<td>Chisel</td>
<td>Ring Toss</td>
<td>Flan</td>
<td>Iris</td>
<td>Pearl</td>
</tr>
<tr>
<td>7</td>
<td>Clamp</td>
<td>Marble</td>
<td>Sushi</td>
<td>Tulip</td>
<td>Onyx</td>
</tr>
<tr>
<td>8</td>
<td>Mallet</td>
<td>Bop-It</td>
<td>Gourd</td>
<td>Statice</td>
<td>Zircon</td>
</tr>
<tr>
<td>9</td>
<td>Roller</td>
<td>Firby</td>
<td>Lychee</td>
<td>Hop</td>
<td>Topaz</td>
</tr>
<tr>
<td>10</td>
<td>Nut</td>
<td>Tinker</td>
<td>Barley</td>
<td>Lilac</td>
<td>Jasper</td>
</tr>
<tr>
<td>11</td>
<td>File</td>
<td>Pogo</td>
<td>Prune</td>
<td>Jasmine</td>
<td>Sunstone</td>
</tr>
<tr>
<td>12</td>
<td>Pliers</td>
<td>Slime</td>
<td>Eggplant</td>
<td>Heather</td>
<td>Amber</td>
</tr>
<tr>
<td>13</td>
<td>Washer</td>
<td>Easel</td>
<td>Sprouts</td>
<td>Aster</td>
<td>Moonstone</td>
</tr>
<tr>
<td>14</td>
<td>Brace</td>
<td>Jump Rope</td>
<td>Wheat</td>
<td>Fressia</td>
<td>Lapis</td>
</tr>
<tr>
<td>15</td>
<td>Hatchet</td>
<td>Slink</td>
<td>Chive</td>
<td>Primrose</td>
<td>Diamond</td>
</tr>
</tbody>
</table>
Table 28

*Sequence of BiN Sets across Participants for Experiment IV*

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
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<td>9</td>
<td>14</td>
<td>13</td>
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<td>9</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>7</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>13</td>
<td>8</td>
<td>5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>2</td>
<td>12</td>
<td>4</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>11</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>1</td>
<td>13</td>
<td>7</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td></td>
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<tr>
<td>12</td>
<td>2</td>
<td>10</td>
<td>7</td>
<td>15</td>
<td>4</td>
<td></td>
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<tr>
<td>15</td>
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<tr>
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<td>7</td>
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<tr>
<td>13</td>
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<td>2</td>
<td>14</td>
<td>8</td>
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<td>6</td>
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<td>4</td>
<td>8</td>
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<tr>
<td>14</td>
<td>5</td>
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<td>11</td>
<td>2</td>
<td>10</td>
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<tr>
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<td>12</td>
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<td>7</td>
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<tr>
<td>2</td>
<td>1</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* I used a list randomizer (random.org) to counterbalance the presentation of stimuli sets across participants.
across the 5 stimuli in a randomly rotated fashion until 20 experiences were conducted. During the experience session, experimenters collected data on voluntary echoics emitted by the participants (e.g. experimenter presents fressia and delivers name “fressia” and participant says “fressia”). Each experience consisted of a novel set of stimuli. Tables 27 and 28 display the stimuli used in Experiment IV.

**BiN probe.** Two hours following a naming experience, I conducted a BiN probe which consisted of opportunities to select and label the stimuli targeted during successive novel naming experiences. I provided each participant two opportunities to respond as a listener to each stimulus within a given set, for a total of 10 listener responses (e.g. “point to ____”), followed by two opportunities to respond as a speaker to each stimulus as a tact (experimenter presented visual stimulus with no vocal antecedent) and intraverbal (e.g. “what is this?”), for a total of 20 speaker responses. Demonstration of UniN was considered >80% accurate listener responses and demonstration of BiN was considered >80% accurate speaker responses. To establish BiN, I used two procedures, (a) Successive Naming Experience with Novel Stimuli (SNENS) followed by single probe sessions for listener and speaker responses and/or (b) Single Naming Experiences with Repeated Probe sessions (SNERP.) until mastery of transformation of stimulus function from listener to speaker. All participants began with SNENS to induce BiN; however, if speaker data decreased to 0 or overall did not increase following 5 sessions or remained a 0 for 2 consecutive sessions, I implemented SNERP. This continued until participants demonstrated BiN across two consecutive novel probes (>80% accurate tact and intraverbal responses).

**Interobserver Agreement (IOA)**
Across probe and intervention sessions, I collected data on the percentage of interobserver agreement (IOA) using a second, independent observer. In addition, I calculated treatment fidelity of experimenter’s implementation of the probe and intervention procedures using the Teacher Performance Rate and Accuracy (TPRA; Ingham & Greer, 1992). IOA was calculated using point-by-point procedures, dividing the total number of correct responses recorded by one observer (the lower of the two totals) by the total number of correct responses recorded by the other observer and multiplying the result by 100 percent. IOA was collected for 42% of derived relation listener training sessions with 100% agreement and 45% of assessments of mutual and combinatorial entailment with 99% agreement. During intervention sessions, I collected IOA for 46% of sessions with 100% agreement. The TPRA was conducted for 8% of all sessions, with 100% agreement of treatment fidelity.

Results

Figures 21 through 23 display results of Experiment IV. Results are described for each graph, temporally, by participant. Figure 21 displays the listener training data across Phases 1, 2, and 3. Figure 22 displays the derived speaker responses following listener training across Phases 1, 2, and 3 and Figure 23 displays intervention data to establish BiN.

Figure 21 displays the percentage of correct responses during listener training across Phases 1, 2, and 3. Criterion for mastery of listener training was considered 90% across two consecutive sessions or 100% across one session, each session consisted of 20 learn units. Participants A and B met criterion for Phase 1 after 2 sessions and Phases 2 and after 3 sessions. Participant C met criterion for Phases 1 and 2 in 3 sessions, and Phase 3 after 7 sessions. Participant D met criterion for Phase 1 after 2 sessions, Phase 2 after 3 sessions, and Phase 3
Figure 2. Figure 2 displays the number of correct responses to listener training for Phases 1, 2, and 3 of the tests of derived relations. This consisted of learn units for pointing to feline, insect, mollusk, and serpent (Phases 1 and 2) and match-to-sample training for matching ver (feline and serpent) and int (insect and mollusk). Criterion was considered 90% x 2 or 100% x 1. The method of authority used was the Decision Protocol (Keohane & Greer, 2005) and Participant F required a stop decision during Phase 3.
after 4 sessions. Participant E met criterion for Phase 1 after 3 sessions, Phase 2 after 5 sessions, and Phase 3 after 6 sessions. Participant F met criterion for Phases 1 and 2 after 3 sessions and a decision to stop Phase 3 was made by the experimenters following 11 sessions with an average of 75% accuracy. Participant G met criterion for Phase 1 after 4 sessions, Phase 2 after 2, and Phase 3 after 6 sessions.

Figure 22 displays the percentage of correct derived listener and speaker relations, including mutual and combinatorial entailment across Phases 1, 2, and 3 during baseline and following each phase of intervention. During pre-intervention, Participant A acquired increasing accurate mutually entailed speaker responses; however, did not acquire combinatorially entailed listener and speaker derived relations. Following mastery of first phase of intervention, Participant A emitted 100% accurate speaker responses. Participant B emitted 100% accurate responses for Phase 1, 50% for Phase 2, and low levels of correct responses for Phase 3. Following 5 phases of intervention, Participant B emitted 100% accurate speaker responses. Participant C emitted few accurate responses for Phases 1 and 2 during baseline and post-intervention sessions, she acquired mutually entailed listener and speaker relations, specifically ver and int, but did not acquire combinatorially entailed speaker responses. Following the establishment of BiN (> 80% accurate listener/speaker responses during a single probe), Participant C demonstrated increased derived speaker responses (mutually entailed) and also 55% increases to combinatorially entailed speaker responses. Following a novel set of stimuli, Participant C demonstrated similar trends in accurate responses.

Participant D acquired few derived relations during pre-intervention sessions. Following one phase of intervention, Participant D increased in mutually entailed listener and speaker responses across Phases 1, 2, and 3. Data remained stable after two additional phases of
Figure 22. Figure 22 displays the percentage of accurate derived listener and speaker responses across Phases 1, 2, and 3 (mutual and combinatorial entailment). Assessments were conducted prior to intervention until no learning occurred and following 60% untrained speaker responses and following each session of 80% untrained speaker responses. Two sets of stimuli with a variety of exemplars were rotated during each assessment. Criterion was considered 80% accurate responses across each phase.
intervention. Following four phases of intervention, Participant D acquired 16% accurate responses for combinatorially entailed speaker relations. Following an additional phase of intervention, Participant D demonstrated 28% correct responses for combinatorially entailed speaker relations with comparable accurate responses for mutually entailed listener and speaker responses.

During baseline sessions, Participant E emitted an average of 50% accurate responses for mutually entailed speaker responses (Phases 1 and 2) with mutually entailed listener and speaker responses (Phase 3) decreasing across baseline sessions. Following one phase of intervention, Participant E emitted 50%, 50%, and 80% accurate responses for mutually entailed listener and speaker responses across the three phases and 11% for combinatorially entailed speaker relations. Following a second phase of intervention, Participant E emitted 100%, 50%, and 90% accurate responses for mutually entailed listener and speaker responses across the three phases and 50% accurate combinatorially entailed speaker relations. Following a third phase of intervention, Participant E emitted criterion-level responding across mutually entailed listener and speaker responses (100%, 100%, 100%) and combinatorially (83%) entailed speaker responses. Participant F acquired criterion-level correct responses during baseline with 0 correct responses for combinatorially entailed speaker relations. Following each phase of intervention, Participant F increased in accurate responses for combinatorially entailed speaker relations, ultimately acquiring 94% accurate responses for these relations following 3 phases of intervention.

Figure 23 displays the intervention data for acquisition of BiN. Participant A emitted 60% accurate speaker responses following 2 sets of stimuli and demonstrated BiN after 6 sets of stimuli. Participant B emitted 60% accurate speaker responses following 2 sets of stimuli.
Figure 23 displays the number of accurate, untrained listener and speaker responses across novel, familiar stimuli using SNENS and SNERP interventions. Criterion was considered 80% accurate responses across two novel sets of stimuli. Tests of derived speaker responses were conducted following 60% for one set of stimuli and following 80% and/or 100% accurate responses across sets of stimuli. The x-axis displays temporal sessions by set of stimuli. The sequence of stimuli sets used across the participants is displayed in Table 28.
Following 7 sets of stimuli with variable data, the experimenter made a decision to switch to SNERP. Participant B demonstrated 80% accurate speaker responses for a novel set of stimuli following one phase of SNERP. Participant C demonstrated 80% accuracy for the first set of stimuli. Following 4 sessions of SNENS with decreasing speaker data, experimenters switched to S.N.E.R.P. Participant C required 7 phases of SNERP intervention prior to demonstrating 80% accuracy on a novel set of stimuli. Participant D demonstrated 60% accurate speaker responses following 2 sets of stimuli. Following an additional 3 sets of stimuli, we implemented SNERP.

Participant D did not meet the criterion for BiN following several phases of SNERP intervention. She did, however, continue to acquire 80% accurate listener and speaker responses following repeated probe sessions. Participant E demonstrated low levels of accurate speaker responses during SNENS. Following 5 sessions, we made a decision to conduct a post probe and continue with SNERP. Participant E required 2 phases of SNERP intervention prior to acquiring criterion-level derived speaker responses for the dependent variable. Participant F demonstrated BiN following two sets of stimuli and demonstrated 100% accurate speaker responses after 3 sets of stimuli.

**Discussion**

Four of six participants demonstrated mastery criterion for derived listener and speaker relations as a function of increased accurate listener and speaker responses for novel, familiar stimuli (degrees of BiN), while the other two participants demonstrated increases in AAR. These results suggest a functional relation between the accuracy of untrained listener and speaker responses for novel, familiar stimuli (establishment of BiN) and the emergence of other arbitrarily applicable relations (AAR). These results demonstrate that the instructional histories for responding to untaught language relations, or the establishment of reinforcement for word-
object correspondence (Greer, 2020), set the occasion for the acquisition of other language relations. Findings support the research suggesting that the demonstration of complex verbal repertoires, specifically naming, may affect the acquisition of other arbitrary relations and basic concepts (Frank, 2018; Kobari-Wright & Miguel, 2014; Miguel & Petursdottir, 2009; Miguel et al., 2008; Morgan, 2018). This is further demonstrated in the acquisition of combinatorial entailment relations following repeated opportunities to respond to novel, familiar stimuli as a listener and speaker. That is, following the emergence of mutually entailed listener and speaker relations for AAR, the establishment of bidirectional operants for novel, familiar stimuli established the necessary learned reinforcers for combinatorial entailment relations to emerge.

These results validate Morgan (2018) and Frank (2018) by suggesting that as participants’ degree of BiN increased so did their accurate responses for other derived relations. Morgan (2018) found in a group descriptive analysis a strong positive correlation between BiN and UniN for unfamiliar stimuli (e.g. symbols) and AAR but not between BiN and UniN for familiar stimuli and non-arbitrary relational responses. Additionally, Frank (2018) found strong positive correlations between BiN and standardized measures of basic concepts, suggesting BiN is a prerequisite for measures of basic concepts. Findings of Experiment III furthered the findings of Morgan (2018) and Frank (2018) by demonstrating that accurate, untrained listener/speaker responses, which can be referred to as transformation of stimulus function (TSF) across listener/speaker for familiar stimuli, functions to increase AAR. This suggests that establishing reinforcement for correspondence across seeing and saying for novel stimuli (word-object relations) are the instructional histories required for other AAR.

Previous literature on the emergence of untrained language relations suggest that complex language repertoires, specifically BiN may be required prior to emergence of these
relations (Frank, 2018; Kobari-Wright & Miguel, 2014; Miguel & Petursdottir, 2009; Miguel et al., 2008; Morgan, 2018). While participants did acquire some demonstration of bidirectional operants, it appears that the demonstration of BiN, as defined by the criterion set forth in previous BiN literature (Fiorile & Greer, 2007; Gilic & Greer, 2011; Greer et al., 2005; Kleinert, 2018; Longano & Greer, 2015) was not required prior to acquisition of other AAR (see Figures 22 and 23). Rather, the rotation across listener and speaker opportunities for novel stimuli with certain degrees of accuracy (or stimulus control) set the occasion for TSF across listener and speaker responses for other AAR to emerge. While Participants B and F demonstrated criterion-level responding for AAR following the onset of BiN, Participant A demonstrated accurate AAR prior to the demonstration of BiN and following 60% accurate speaker responses for a novel set of stimuli, he acquired all AAR. Participant E acquired 83% accurate combinatory entailment relations; however, did not demonstrate 80% accurate listener/speaker responses with a novel set of stimuli. These results further suggest that BiN is not present or absent within one’s instructional history, but rather a continuum for which other arbitrary listener and speaker relations emerge (Frank, 2018).

Similar to the serendipitous findings reported in Experiment III, in the absence of correct speaker responses, Participants C and D often emitted incorrect responses which held some correspondence to the target responses. These responses may have been previously reinforced under similar environmental contingencies in their instructional histories, referred to in experimental psychology literature as proactive inhibition (Craik & Birtwistle, 1971; Keppel & Underwood, 1962; Wickens, 1970). For example, when asked to emit intraverbal tacts to the stimulus class “serpent”, Participants B, C, and D responded with “snake” or “worm”, both during tests of mutual and combinatorial entailment. However, following increases in degrees of
BiN, Participant B replaced “worm” with “serpent” for all target responses (see Figure 23), which was the target response. This was not observed with Participants C and D, suggesting that prior stimulus control for such responses were stronger and participated in categorical responses. That is, the necessary degree of TSF for word-object relations was not sufficient to compete with previously reinforced responses. Such findings warrant continued investigation through similar assessment using contrived stimuli (Lo, 2016). Interestingly Participant C emitted a target response for Phase 1 mutual entailment (“feline”) following establishment of BiN as well as combinatorial entailment which required the conditionally related intraverbal tact (e.g. “ver” or “int”). Participant D demonstrated similar trends with combinatorial entailment relations. She did not acquire combinatorial entailment relations for which target responses required the mutually entailed speaker responses to be emitted (e.g. “serpents are ver, what is another animal that is ver?”).

Limitations of Experiment IV warrant mention. Participant A emitted high parentages of correct response across mutual and combinatory entailment relations during baseline sessions. Across all four baseline sessions, Participant A consistently responding incorrectly to a specific response topography, intraverbal tact responses for Phase 3. Upon presenting a visual (e.g. feline) and providing the antecedent “felines are ver, what is another animal that is ver?” to which the correct response was “serpent”, Participant A consistently responded by providing a tact for the visual (e.g. “feline”). Following two sessions of intervention using SNENS in which Participant A emitted 60% accurate speaker responses, Participant A emitted 100% accurate responses for mutual and combinatory entailment relations. These findings further demonstrate the findings mentioned above; however, Participant A and B entered the study as a dyad given the high numbers of correct responses during baseline.
Further, experimenters entered Participant F into intervention prior to Participant E demonstrating 60% accurate listener and speaker responses. Participant E received several phases of intervention using SNENS in which speaker data remained low and variable, ultimately leading us to enter Participant E into SNERP intervention procedures. At this point, Participant F entered intervention as it was educationally significant to induce BiN. Given that both Participant E and F demonstrated mastery criterion for mutual and combinatorial entailment, it does not appear that this limitation affected the results.

The findings reported herein warrant continued research on the sources on reinforcement responsible for all language relations. Given the demonstration of other AAR as a function of bidirectional operants, it appears that considering BiN as a continuum and not a present or absent repertoire allows for other collateral benefits to emerge (Frank, 2018). To address the limitations of Experiment IV, specifically why two participants did not demonstrate criterion-level responding for mutual and combinatorial entailment, continued research is warranted on arranging stimuli that may control for proactive inhibition, such as use of unfamiliar visual and auditory stimuli. Future research should consider parametric analysis for degrees of BiN and other arbitrary relations and assessing for the emergence of BiN for familiar and unfamiliar stimuli. It seems that continued, interdisciplinary research on emergent language relations may align the foci of accounts of verbal behavior (Barnes-Holmes et al., 2000; Dymond & Barnes, 1995; Greer & Longano, 2010; Greer & Ross, 2008; Greer & Speckman, 2009; Hayes et al., 2001; Roche et al., 2000).
Chapter VI

GENERAL DISCUSSION

In a series of studies, I evaluated the effectiveness of procedures for measuring degrees of BiN and the relations between the onset of BiN and other derived relations across toddler-aged participants. Findings of these studies are consistent with the body of literature on verbal behavior suggested that the UniN emerges initially prior to BiN (Greer et al., 2005; Gilic & Greer, 2011; Frank, 2018) and that one’s verbal behavior significantly influences their acquisition of other relations and repertoires (Frank, 2018; Hranchuk, 2016; Kobari-Wright & Miguel, 2014; Morgan, 2018). The findings reported herein contribute significantly to the body of research in demonstrating the source of reinforcement responsible for some emergent, equivalent language relations may be a history of reinforcement for correspondence (Barnes-Holmes et al., 2000; Dymond & Barnes, 1995; Greer & Longano, 2010; Greer & Ross, 2008; Greer & Speckman, 2009; Hayes et al., 2001; Kobari-Wright & Miguel, 2013; Miguel & Kobari-Wright, 2013; Miguel & Petursdottir, 2009; Miguel et al., 2008; Morgan, 2018; Roche et al., 2000).

Major Findings of Experiments I and II

Results of Experiments I and II are consistent with previous research findings on BiN which strongly demonstrate that children acquire UniN, or emergent listener responses, prior to the joining of listener and speaker responses, or the emergence of BiN (Frank, 2018; Gilic & Greer, 2011; Greer et al., 2005; Greer & Speckman, 2009; Kleinert, 2016; Longano & Greer, 2015). The purpose of Experiment I was (1) to identify if significant correlations exist between voluntary echoics and measures of BiN using an attempted storybook naming experience (Farrell et al., 2018) and (2) to demonstrate if successive exposures with identical visual and auditory
stimuli affect the measures of BiN across toddler-aged participants ($N=24$) with a mean age of 28 months old.

Findings of Experiment I revealed no significant correlations between voluntary responses during the naming experience and accuracy of listener/speaker responses. Recently, experimenters investigated the sources of reinforcement for BiN and found strong correlations between the number of voluntary echoics emitted and the emergence of BiN (Longano & Greer, 2015). Given a storybook naming experience, which contained target auditory and visual stimuli embedded into story content, there was often a delay between target auditory stimuli and visual stimuli. In delivering the experience (e.g. “Koop ate french fries” while presenting the visual of Koop; see Appendix A), the experimentally defined response was “Koop”; however, due to the delay and additional auditory stimuli (e.g. “ate french fries”), these responses were not echoics. Echoic responses are defined as auditory stimuli emitted immediately following a vocal antecedent and Skinner (1957) distinguished between echoic behavior and “later reproduction of overheard speech” (p. 59). Embedding the target auditory stimuli into storybook content limited the number of echoic opportunities the participants received, providing a possible explanation for the limitation in significant correlations. These findings suggest the potentially immense role of proximate opportunities to echo auditory stimuli while observing novel, visual stimuli in the acquisition of bidirectional operants.

With regards to measures of BiN, results of Experiment I suggested that the storybook naming experience resulted in the acquisition of UniN but did not result in BiN across 24 toddler-aged participants. Following three successive exposures to the storybook naming experience, participants acquired an average of three operants as a listener; however only one bidirectional operant. Previous literature on the emergence of BiN following repeated naming
probes demonstrated that transformation of stimulus function from listener to speaker emerged for students with strong stimulus control for UniN (Lo, 2016; Kleinert, 2018). Target auditory stimuli within the storybook were both one (e.g. “Koop”) and two-syllables (e.g. “Lavern”). Anecdotal observations of correct responses suggested that participants more readily acquired bidirectional operants for the auditory stimuli with fewer syllables. These noted observations suggest a potential relation between one’s speech articulation and the acquisition of bidirectional operants.

The aim of Experiment II was to test if one’s phonemic responses, or speech articulation, was functionally related to the emergence of BiN. That is, can children acquire bidirectional operants for auditory stimuli that they cannot echo with point-to-point correspondence? To test these findings using a storybook naming experience, we assessed if echoic clarity was a variable to control for when assessing for BiN in toddler-aged participants. Results of Experiment II suggest that measures of BiN were not affected by echoic clarity and speech articulation may not be functionally related to the emergence of bidirectional operants. Literature on the sources of reinforcement responsible for the onset of BiN emerge from initial naming theory proposed by Horne and Lowe (1996) which suggest the echoic plays a vital role in the Naming Loop. VBD theorists further proposed the echoic as a source of reinforcement responsible for the establishment of BiN such that as auditory and visual simultaneously select out one’s attention, the echoic functions as the reinforcer which results in transformation of stimulus control from the initial listener response to the speaker response (Greer & Longano, 2010; Greer & Speckman, 2009; Longano & Greer, 2015). Cao and Greer (2019) found a functional relation between mastery of echoic clarity and the emerge of BiN suggesting that a history of reinforcement for
hear-say correspondence functions as a prerequisite for see-say correspondence, or incidental language learning.

Implications of the first two studies suggest that BiN may emerge following only direct, simultaneous experiences with word-object relations in toddler-aged participants (Gilic & Greer, 2011), whereas a storybook naming experience requires more complex conditioned reinforcers for observing responses. The extensive body of literature on the establishment of BiN suggest bidirectional operants emerge following the establishment of conditioned reinforcement for multiply controlled observing responses (Greer & Longano, 2015). Findings of Experiments I and II provide further evidence that in the absence of proximate experiences of both auditory and visual stimuli, toddler-aged participants do not acquire bidirectional operants.

**Major Findings of Experiment III**

The goal of Experiment III was to examine the role of temporal proximity of visual and auditory stimuli on the onset of BiN for novel, familiar stimuli. Findings demonstrated that simultaneous pairings of auditory and visual stimuli (classical conditioning) compared to delayed pairings of visual and auditory stimuli (operant conditioning) did not result in significant difference across measures of BiN. Interestingly, participants with stronger degrees of stimulus control for bidirectional operants demonstrated BiN more reliably under delay conditions than simultaneous conditions (see Figure 15). However, overall results did not strongly suggest that one method of presentation resulted in stronger stimulus control for bidirectional operants.

In investigating the reinforcers responsible for the compelling differences in Participant A and B’s demonstrations of BiN during delayed naming experiences, or operant conditioning procedures, it appears that the sequence of stimulus presentation did affect the acquisition of bidirectional operants. All of the participants reliably echoed the auditory stimulus during
naming experiences (see Figure 14), compared to Experiments I and II. However, the one second delay between the experimenter’s presentation of the visual stimulus (e.g. picture of a ferret) and the auditory stimulus (“ferret”) provided an opportunity for the auditory stimulus potentially be acquired as an independent tact (see Figure 14). That is, within the delay conditions, the establishing operation (EO) for the see-say correspondence was stronger such that the participants may acquire a speaker operant during the experience. These participants thus required fewer experiences to acquire untaught speaker responses, which is consistent with previous literature suggesting the number of experiences required to acquire bidirectional operants differs given one’s prerequisite cusps/capabilities (Hranchuk, 2016). Participants A and B acquired significantly more tacts during the delayed experiences than the remaining four participants. These findings such a relation between “need to know” motivating conditions and the joining of listener and speaker responses (Greer & Longano, 2010; Greer & Speckman, 2009; Longano & Greer, 2015).

Serendipitous Findings of Experiment III

While participants did not reliably differ in measures of BiN across the two proximity conditions, the results of Experiment III yielded serendipitous findings that differed from the initial research questions. Across the participants, incorrect speaker responses shared similar characteristics which related to recent research in the field of behavior analysis (Frank, 2018; Kobari-Wright & Miguel, 2014; Miguel & Kobari-Wright, 2013; Miguel et al., 2008; Morgan, 2018). Following direct pairings of visual and auditory stimuli (incidental naming experience), in the absence of a correct, target tact during a subsequent naming probe, participants categorized visual stimuli with auditory stimuli that had previously resulted in reinforcement. For example, if
presented with a visual stimulus such as oboe, participants emitted responses such as “piano”, which is visually related to oboe, or “instrument” which is a categorization response.

All of the participants demonstrated reliable UniN regardless of temporal proximity conditions, while BiN was not reliably demonstrated across the participants. Experiment III post-intervention probes across listener and speaker derived relation assessment revealed the emergence of categorization as a listener across six participants and few accurate responses to categorization responses as a speaker (see Figure 16). These data suggest a relation between UniN and other derived listener responses and BiN and the establishment of other derived listener and speaker responses.

Research on incidental language acquisition suggest that one’s verbal behavior repertoire, specifically emergent word-object relations, may facilitate the acquisition of derived relations (Kobari-Wright & Miguel, 2014; Miguel & Kobari-Wright, 2013; Miguel & Petursdottir, 2009; Miguel et al., 2008). Across two experiments, Miguel et al. (2008) found that three- to five-year-old children could acquire stimuli as a category or class only following mastery of word-object relations as a listener and a speaker, with some participants requiring additional sessions of intervention prior to acquisition of experimentally defined categories. Miguel and Kobari-Wright (2013) further validated relations between naming and other derived relations by demonstrating a relation between incidental language acquisition for names of novel objects and categorizations across preschools diagnosed with autism. A subsequent study evaluated the effects of listener training on the emergence of bidirectional operants and categorization (Kobari-Wright & Miguel, 2014). Results suggested that following listener training participants acquired speaker responses for target stimuli and novel categorization responses. Morgan (2018) further validated these studies using a group descriptive analysis ($N = 31$) in which participants who measures of BiN
for unfamiliar stimuli (e.g. Chinese phonemes) were strongly correlated with the establishment of other, arbitrary derived relations.

**Major Findings of Experiment IV**

Experiment IV was implemented to evaluate the unanticipated findings of Experiment III. Results of Experiment IV further validated findings of Morgan (2018) in demonstrating significant increases in arbitrarily applicable, or verbally mediated contextually controlled, relations following the establishment of BiN across toddler-aged participants. The present study added to the findings of Morgan’s (2018) study by demonstrating that interventions to induce BiN for familiar stimuli function to increase other bidirectional relations. These findings further validate literature suggesting one’s verbal repertoire, specifically the acquisition of bidirectional operants as a listener and a speaker, influence the acquisition of derived relations (Kobari-Wright & Miguel, 2014; Miguel & Kobari-Wright, 2013; Miguel et al., 2008).

The implementation of two interventions to induce BiN emphasized the importance for attending to individualized instructional histories when assessing for the presence of verbal behavior developmental cusps and cusps that are capabilities. While all of the participants entered under the SNENS intervention which consisted of novel stimuli presented during each session of intervention, only two of the participants demonstrated BiN under these conditions (see Figure 22). Previous data suggest that a relation between the number of experiences an individual requires prior to the acquisition of a stimulus as a bidirectional operant (Hranchuk et al., 2018; Longano & Greer, 2015); however, there is a limited body of research comparing successive novel stimuli and the onset of BiN. Two participants demonstrated variability in their accurate speaker responses during the SNENS intervention, while two participants demonstrated steep decreases in accurate speaker responses during the SNENS intervention. These findings
suggested that Participants A and F demonstrated the strongest stimulus control for bidirectional relations by demonstrating BiN following a single naming experience. This is consistent with Hranchuk et al.’s, (2018) findings which suggested that participants with more complex verbal behavior required fewer numbers of exposures to acquire the names of novel stimuli as a listener and a speaker.

Providing participants with a single naming experience followed by repeated listener and speaker probes until transformation of stimulus function from listener to speaker (SNERP) functioned to increase degrees of BiN across the four participants who did not demonstrate increases through SNENS. Previous studies evaluating the effectiveness of interventions to induce BiN across individuals with UniN found that repeated probe interventions functioned as a conditioning procedure to transfer stimulus control from listener responses to bidirectional operant (Lo, 2016; Kleinert, 2018). It appears that the SNERP intervention provided the reinforcement necessary for the participants to acquire single bidirectional operants during each successive probe until mastery-level criterion.

In a series of studies, Frank (2018) defined BiN as a continuum and discussed an individual’s degree of BiN as a more effective method for defining the repertoires. Previous literature on BiN discuss BiN as a categorial variable with an individual demonstrating either the presence or absence of the capability (Greer et al., 2005; Gilic & Greer, 2011; Hranchuk et al., 2018). Frank (2018) found that discussing BiN as a continuous variable lead to more accurate correlational analyses and further emphasized the importance of individualizing the description of one’s verbal behavior repertoire. Although there is limited research investigated the criterion for the presence of BiN, VBD research suggests an arbitrary criterion of 80% accurate listener and speaker responses across two sets of stimuli as criterion for demonstration of BiN (Fiorile &
In Experiment IV, participants demonstrated continual increases in mutually and combinatorially entailed relations as they acquired bidirectional operants. That is, as the stimulus control for bidirectional operants increased, stimulus control for other derived relations increased. These findings further suggested that sources of reinforcement for BiN may make other emergent language relations possible.

While all of the participants demonstrated significant increases in accurate arbitrary relations, two of the participants did not demonstrate the predetermined criterion for emergence of derived relations. Participants B, C, and D demonstrated patterns in incorrect responses which mirrored those identified in Experiment III. These incorrect responses may have been previously reinforced under similar contingencies in their instructional histories, or proactive inhibition (Craik & Birtwistle, 1971; Keppel & Underwood, 1962; Wickens, 1970). Proactive inhibition within experimental psychology literature is investigated as a potential variable which interferes with acquisition of learning tasks. This interference has been demonstrated to occur in the “short-term retention of verbal material” (Craik & Birtwistle, 1971; Keppel & Underwood, 1962) and the effects can be minimized with changing certain characteristics of the targeted stimuli (Wickens, 1970).

Interestingly, following increased stimulus control for bidirectional operants, Participant B acquired experimentally defined responses across mutual and combinatorial entailment, while Participants C and D did not. A possible explanation for the limited increases in two participants may include that other non-arbitrary (visually) related stimuli, which, when emitted in one’s instructional history resulted in reinforcement, had stronger stimulus control than the listener.
responses trained. Such limitations warrant continued research on the sources of reinforcement for emergent language relations.

**Reinforcement for Correspondence**

Given that four of the six participants demonstrated mastery criterion for derived relations, another theory may be that the source of reinforcement for BiN, a history of reinforcement for correspondence (see-say correspondence), may be the source of reinforcement responsible for other emergent language relations (see Figure 24; Greer, 2020; Greer & Du, 2014; Greer & Longano, 2010; Greer et al., 2017). Findings of Experiment IV are consistent with previous literature in suggesting the onset of reinforcement for bidirectional operants is the correspondence between seeing an object and producing the spoken word paired with that object during previous experiences (Carnerero & Perez-Gonzalez, 2014; Greer, 2020; Greer & Longano, 2010; Greer & Speckman, 2009). The results of Experiment IV further validate previous findings in suggesting that the correspondence, see-say correspondence, functioned to reinforce the emergence of other derived listener and speaker relations (Frank, 2018; Greer, 2020; Morgan, 2018).

A history of correspondence as a reinforcer can be seen throughout an individual’s verbal developmental trajectory as they acquire “sameness” as a reinforcer (Greer & Ross, 2008). Generalized Match-to-Sample (MTS; Delgado, Greer, Speckman, & Goswami, 2009; Greer & Han, 2015), generalized imitation (see-do correspondence), advanced phonemic awareness (Choi et al., 2015) are pre-verbal foundational and speaker cusps that demonstrate the acquisition of correspondence as a reinforcer. Generalized MTS is a cusp that once present, provides one the repertoires necessary to acquire visual sameness in the absence of direct training (Greer & Han, 2015). The emergence of identifying sameness functions as a prerequisite for learning visual
Figure 24. Figure 24 displays the percentage of correct responses for derived listener and speaker responses across three phases (y-axis) as the participants acquired more bidirectional operants during intervention (displayed as cumulative number on the x-axis). This graph displays a similar slope across the participants who demonstrated mastery criterion for other derived relations, while data for Participants C and D do not.
discriminations (Engelmann & Carnine, 1991) and for learning the names of things. Generalized imitation is a cusp that is a learning capability that, when present, allows one to observe another’s actions and imitate them, in the absence of direct training (Du & Greer, 2014), or see-do correspondence. As one acquires speaker behavior, advanced phonemic awareness, or auditory Match-to-Sample (MTS; Choi et al., 2015), is the onset of echoic or speech-sound correspondence. This provides repertoires necessary for one to produce sounds and words with point-to-point correspondence to a spoken antecedent, referred to as hear-say correspondence.

BiN is a verbal behavior developmental cusp (Rosales-Ruiz & Baer, 1996) that, once present, is a new learning capability (Greer & Du, 2015; Greer & Longano, 2010; Greer & Speckman, 2009) defined by the joint stimulus control for listener and speaker responses such that experiencing a listener response occasions the tact response (Greer et al., 2005). BiN can be considering an extension of the reinforcement for correspondences described above to see-say correspondence. That is, the motivating conditions during the observation of a novel object while hearing a caregiver provide the given name of the object reinforcers one to produce that name during future exposures to similar objects.

As such, reinforcement for correspondence may be the source of reinforcement responsible for other emergent language relations. Extensive research on BiN suggest the implications following its onset (Greer et al., 2005; Gilic & Greer, 2011); however, there are limited evidence-based studies evaluated the implications as one acquires this learning capability (Frank, 2018; Morgan, 2018). Results of Experiment IV suggest this in the increases of arbitrary relations following repeated BiN probes (see Figure 24). In considering BiN as a continuous variable (Frank, 2018), we can more accurately measure collateral benefits as one acquires word-object relations. A general term such as, generalized bidirectional operants, may
comprehensively encompass all emergent, cross-modal language relations given the overlap suggested by the current body of research.

Analyzing the results of Experiment IV revealed that the derived relations increased as a function of increased bidirectional operants, rather than the onset of BiN. Figure 24 displays the percentage of correct derived listener and speaker responses as a measure of cumulative bidirectional operants acquired during intervention. To provide one example, following the acquisition of four bidirectional operants, Participant B demonstrated minimal increases in other derived relations compared to baseline. However, following the acquisition of another six bidirectional operants derived relations slightly increased. Then following acquisition of an additional 16 bidirectional operants, Participant B demonstrated 100% accurate derived relations. These results further suggest that untrained language relations may emerge as a “magnet” (Longano, 2019), such that as operants are acquired others emerge.

Families of relational frames categorize increasingly complex ways to relate stimulus events (Hayes et al., 2001). Frank (2018) demonstrated that certain stimulus relations are more basic than others, which is consistent with the findings in the frame of RFT (Barnes-Holmes et al., 2004). Emergent naming, BiN, is classified as a frame of coordination (Hayes et al., 2001) or the emergence of equivalent relations. The relation trained and assessed in Experiment IV can be classified as combined frames of coordination and frames of hierarchy. Hierarchical relations, which define frames of comparison that can be most related to common categorization, define more complex relations. Hayes et al. (2001) define hierarchical frames as a stimulus event described along a specific dimension with regards to another event; however, the relative quantity or quality is relative to the other stimulus event. For example, if it is trained that “Bob is
the father of Dave and Barb” (Hayes et al., 2001, p. 37), the one can derive that Dave and Barb are siblings.

According to Hayes et al., (2001), “hierarchical relations are extremely important in the analysis of the use of verbal relations to abstract properties of the nonarbitrary environment” (p. 37). With regards to Experiment IV, the emergence of bidirectional operants, or frames of coordination, functioned as the prerequisite stimulus control which function to establish other frames of coordination (mutually entailed relations) and more complex relations, such as hierarchical relations (combinatorially entailed relations). These findings add to the body of literature on the merging of word learning and other contextually controlled language relations.

**Educational Implications**

Decades of research on verbal behavior development focus on the evaluation of interventions which provide an individual with experiences and instructional histories that result in the establishment of new reinforcers and new ways of learning (Greer & Du, 2015; Greer & Longano, 2010; Greer & Speckman, 2009; Greer & Ross, 2008; Longano & Greer, 2015). There is an extensive body of literature demonstrating the implications following the establishment of BiN (Frank, 2018; Helou-Care, 2008; Hranchuk et al., 2018). Once BiN is established, an individual can learn in new ways (Greer, 2008; Greer & Ross, 2008; Keohane & Greer, 2006). For example, students with no incidental Naming (NiN) cannot benefit from teacher models, IDLU’s, while, students with UniN and BiN can acquire listener, and speaker, skills following IDLU’s (Frank, 2018; Hranchuk et al., 2018). However, there is limited research on the implications as one acquires BiN, when considering BiN as a continuum.

The findings of this study and previous studies suggest that individuals with UniN can acquire other derived relations as they acquire the conditioned reinforcement for see-say
correspondence and thus acquire these skills as at an accelerated rate. In Experiment III, it became apparent that individuals with strong stimulus control for unidirectional operants, and increasing stimulus control for bidirectional operants, may acquire relational frames across listener and speaker responses (Hayes et al., 2001) following environmental experiences with word-object relations (i.e. naming experiences). Instructional practices should be centered around individualized capabilities such that one’s instructional history is considered when identifying the tools and assessments that will result in accelerated learning. Present findings should be considered when developing programs for students and training protocols for teachers to incorporate assessment of collateral, emergent language acquisition, such as basic concepts (Frank, 2018) and other arbitrary relations (Morgan, 2018).

Results of Experiment IV add to the body of literature by suggesting BiN as a facilitator for other language relations and overall academic proficiency. Experiment IV suggested that as an individual acquires joint stimulus control for listener and speaker responses, or derived bidirectional operants, other derived relations emerge for four participants. That is, BiN may be a prerequisite for, emergent categorization (Greer & Longano, 2010). Frank (2018) found significant correlations between degree of BiN and performance on standardized tests of basic relational concepts. Such basic relational concepts constitute a large part of most standardized, intelligence assessments (Flanagan, Alfonso, Kaminer, & Rader, 1995).

Greer and Longano (2010) suggest that the consideration of BiN as a facilitator for other emergence equivalence relations may fulfill research questions regarding equivalence relations. Empirical findings related to BiN, its acquisition, and potential sources of reinforcement suggest that responses measured may always relate to some aspect of categorization, although emergent word-object relations do not require abstraction (Greer & Longano, 2010). The joining of
observing and producing responses may exponentially advance other verbal abstractions (Greer & Longano, 2010). Results of Experiment IV together with previous findings (Frank, 2018; Kleinert, 2018; Morgan, 2018) empirically support this research gap in suggesting the sources of reinforcement for word-object relations and other arbitrary relations, such as animal classes, may emerge from identical sources of reinforcement. It appears that the joint attention which occurs during a naming experience (i.e. observing responses paired with auditory stimulus of a given name) result in emergent speaker responses regardless of given context (e.g. names of things, animals class, etc.; Harms, 2019). To increase educational outcomes, individuals who do not acquire UniN or BiN via natural contingencies should enter interventions such as MEI (Greer et al., 2005), ITI (Delgado & Oblak, 2007), or SNERP interventions to induce the capability at an accelerated rate (Greer & Keohane, 2005; Greer & Ross, 2008; Greer & Speckman, 2009).

The implications of these findings extend beyond an academic context to multidisciplinary service providers and caregivers. Basic relational concepts are an essential section of language acquisition which is more abstract than vocabulary, yet significantly predicts proficiency in academics and standardized assessments (Bracken, 1987; Flanagan et al., 1995). Given that a battery of standardized tests is the empirical basis for diagnosis of disabilities, the findings are particularly relevant to school psychologists and related providers. Direct opportunities for “experiences” of auditory and visual stimuli during assessments may result in more sensitive outcomes. At this stage of development, additional prompts (e.g. directions) provided during assessments batteries (e.g. scripted antecedents) may interfere with overall normative scores, as demonstrated in Experiments I and II. The relation between acquisition of word-object relations (e.g. vocabulary) and the emergence of other language relations (e.g. concepts) suggests this may be evident during testing batteries and may offer insight into
particular repertoires of a child that can become achievable goals across other disciplines of service (e.g. speech therapy). These findings can further aide parents in identifying when their toddlers acquire certain verbal behavior milestones. Providing effective ways to identify such milestones across parents and providers may improve overall academic and social outcomes. Overall these implications suggest continued merging of foci of language development to provide a comprehensive and multi-disciplinary approach to early language skills.

**Limitations**

One limitation of the first experiment was the number of exposures to stimuli was standard across the participants, rather than dictated by trends in measures of BiN. As a result, results were limited to correlations across three repeated naming experiences and probes. Continued exposures to stimuli and subsequent measures of accurate listener and speaker responses may have resulted in demonstrations of BiN and further analysis of correlations may have included the number of exposures using a storybook for toddler-aged participants to demonstrate BiN. In addition, the sample size ($N = 24$) was small compared to other descriptive group analyses.

In Experiment II, auditory stimuli consisted of only one syllable contrived consonant-vowel-consonant (CVC) words, which were then coded as fully articulate words or partially articulated words. Limiting the target stimuli to only one syllable may have influenced measured of BiN. Increasing the syllabic complexities (e.g. one-syllable, two-syllable, etc.) may have resulted in more compelling differences in measures of BiN, as a function of syllabic complexities. The number of participants in Experiment II was limited to four participants, all of whom were neurotypically developing. This affected the external validity and overall generality
of the findings. Further, the limitations regarding the standard number of experiences and subsequent listener and speaker probes remained a limitation of Experiment II.

The alternating treatments design used in Experiment III limited the analysis of differences in degrees of BiN demonstrated between two naming experiences. Because BiN is a learning capability, the design selected did not control for potential learning effects and thus minimizing the overall results. Given the unanticipated nature of the serendipitous findings of Experiment III, experimenters did not conduct pre-intervention probes for tests of derived listener and speaker relations. However, these limitations led to a further analysis of the findings.

Limitations of Experiment IV included participant selection and interfering instructional histories in two of the participants. During listener training and baseline assessment of derived relations, Participant A demonstrated near criterion level responding for mutual and combinatorial entailment relations. He continued through intervention as he repeatedly responded incorrectly to one response type. Participant F demonstrated similar trends across all tests of mutual entailment suggesting some learning occurred during baseline conditions; however, she did not acquire combinatorially entailed relations. Interestingly, Participant F demonstrated BiN during her initial session of intervention, although she demonstrated UniN prior to onset of listener training. These results suggest that the rotation of the simple-to complex (STC) protocol between listener and speaker responses may have functioned to induce BiN.

Additionally, the proactive inhibition (Craik & Birtwistle, 1971; Keppel & Underwood, 1962; Wickens, 1970) emitted by two of the participants during pre- and post-intervention tests of derived relations limited the findings of Experiment IV. While four of the participants acquired experimentally defined target listener and speaker responses, two of the participants did not acquire strong stimulus control for experimentally defined responses. Given that the stimuli
targeted in Experiment IV were disparate stimuli that were not visually related to one another, the motivating conditions for the assessed derived relations was the need for coherence. The two participants who did not demonstrate convincing changes in their derived relations had stronger stimulus control for other, non-target responses. This somewhat limited the internal validity of the study and suggests the need for continued intervention into the sources of reinforcement that make BiN and other derived relations possible. It appears that the proactive inhibition for relevant stimuli used during baseline measures (e.g. animals) may have interfered with the transformation of stimulus function for these two participants.

**Future Research**

Given the contributions of the reported findings, future research should address the limitations mentioned above to improve the external validity of the findings to a broad population including participants with different levels of verbal behavior. Results of Experiment II suggest research should further examine the complexities of syllables of auditory stimuli on measures of BiN. Empirical research in echoic training and BiN suggest that following echoic training for novel speech-sound patterns function to establish BiN in preschool-aged children (Cao & Greer, 2019). Using only one syllable words may not have revealed compelling differences in measures of BiN; however, comparison of one, two and three-syllable words across toddler-aged participants may suggest a functional relation between speech articulation and BiN.

Several interventions have been found to establish BiN and each intervention requires certain prerequisites. MEI (Greer et al., 2005) functioned to induce BiN for students with limited incidental listener and speaker responses, while ITI (Delgado & Oblak, 2007) and repeated probes (Lo, 2016; Kleinert, 2018), identified as SNERP in this study, join stimulus control across
listener and speaker responses for some participants who demonstrate UniN. Results of Experiment IV demonstrated two interventions for inducing BiN, SNENS and SNERP. It appears that SNERP functions to strengthen the stimulus control for joining of listener and speaker responses, while SNENS required stronger stimulus control for joining of listener and speaker responses. Two of the participants demonstrated reliable BiN using SNENS, while four of the participants required SNERP to demonstrate BiN. Future research should examine the continuum of BiN as it relates to certain interventions that function to establish the learning capability.

In considering BiN as a continuum, future research should evaluate mastery criterion for demonstration of incidental language learning. Previous studies suggest educators use mastery criterion to evaluate acquisition of novel repertoires; however, research is limited (Fuller & Fienup, 2018). Considering few of the participants in Experiment IV demonstrated BiN using criterion defined in previous literature (Frank, 2018; Greer et al., 2005; Gilic & Greer, 2011; Morgan, 2018), yet demonstrated significant increases in other derived relations, research is warranted on mastery criterion associated with BiN. In Experiment IV, the establishment of BiN resulted in increased accurate derived speaker relations following mastery of listener relations, as a function of increased number of bidirectional operants, rather the demonstration of BiN.

To address the limited acquisition of stimulus control for experimentally defined derived relations across two of the six participants in Experiment IV, continued research is warranted. In Experiment IV, familiar stimuli were used (e.g. animals were available across instructional and non-instructional settings in the participants daily environment). Replication of procedures using contrived auditory and visual stimuli may address the noted limitations. While studies have shown that familiar picture stimuli result in acquisition of frames of coordination (Arntzen &
Lian, 2010; Morgan, 2018); results of Experiment IV suggest that participants with strong stimulus control for certain familiar stimuli did not acquire the experimentally relevant responses. For students with such repertoires, listener training for contrived visual and auditory stimuli may result in acquisition of arbitrary relations to criterion-level.

Future research should continue to examine the reinforcement that makes the establishment of BiN and other derived relations possible. While the reinforcement for BiN may make it possible for the acquisition of other derived relations, there may be another source of stimulus control that make the establishment of BiN and other derived relations possible. Morgan (2018) proposed research should investigate induction of one variable (e.g. BiN) and measure changes to the remaining variable (e.g. derived relations). In this study, experimenters found that in inducing BiN, other derived relations emerged; however, continued research is warranted on the opposite relation. Findings of this study would contribute to the field of verbal behavior in suggesting whether one repertoire is a prerequisite stimulus control to the other, or if the source of reinforcement is the same for both, can they be trained and assessed inversely.

Conclusion

The goal of this study was to contribute to the cumulative body of research on BiN and the establishment of other derived relations (Frank, 2018; Greer, 2020; Kobari-Wright & Miguel, 2014; Miguel & Kobari-Wright, 2013; Miguel et al., 2008; Morgan, 2018). Results of Experiments I and II suggested that toddler-aged participants may require direct experiences to acquire language incidentally, while results of Experiment III suggested a potential relation between BiN and other language relations. Experiment IV significantly contributed to the literature by demonstrating the emergence of mutual and combinatorial entailment relations as a function of the establishment of increased stimulus control for BiN across four of six
participants. It may be that an all-encompassing term such as *generalized bidirectional operants* suggests a comprehensive repertoire of functionally equivalent language relations (e.g. naming, frames of coordination, etc.). Further, in order to improve academic achievement and efficient teaching practices for toddler-aged students with certain prerequisites, when assessing for measures of BiN, practitioners should also include measures of other derived language relations. The current body of research has implications on the facilitation of BiN to establish other cross-modal relations and merge foci of various accounts of verbal behavior to suggest a potential future integration for research in the analysis of verbal behavior.
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Figure A. A sample page of the storybook naming experience used in Experiment I. For the given experience, the experimenter presented the page to the participant, pointed to the target visual stimulus and provided the vocal antecedent written on the page, “Trent ate French fries.” I collected data on whether or not the participant voluntarily said the target auditory stimuli, in this example, “Trent”.

Appendix A

Page of Storybook Naming experience used in Experiment I
Appendix B

Experiment III Test for Arbitrary Relations

Figure B1. A sample slide of the test for derived probe listener response in Experiment III. For the given slide, experimenters presented the slide, gained the participants attention and delivered the antecedent “point to ____” (e.g. “point to animal”) for 5 opportunities across 4 categories for a total of 20 responses. No consequence was delivered for correct or incorrect responses.
Figure B2. A sample slide of the test for derived probe speaker response in Experiment III. For the given slide, experimenters presented the slide, gained the participants attention and delivered the antecedent “what category?” for 5 opportunities across 4 categories for a total of 20 responses. No consequence was delivered for correct or incorrect responses.
Figure B3. A sample slide of the test for derived probe speaker-to-listener response in Experiment III. For the given slide, experimenters presented the slide, gained the participants attention and delivered the antecedent “____ goes with…” (e.g. “radish goes with ____” and the correct response for this example would be the participant pointing to cabbage”) for 5 opportunities across 4 categories for a total of 20 responses. No consequence was delivered for correct or incorrect responses.