Spring 2020

Comparison of Motor-Enhanced and Visual-Enhanced Interventions for Grammar in Young Children With Developmental Language Disorder

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COMPARISON OF MOTOR-ENHANCED AND VISUAL-ENHANCED INTERVENTIONS

FOR GRAMMAR IN YOUNG CHILDREN WITH DEVELOPMENTAL LANGUAGE

DISORDER

by

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A Dissertation Submitted to the Faculty of Old Dominion
University in Partial Fulfillment of the Requirements for the
Degree

DOCTOR OF PHILOSOPHY

SPECIAL EDUCATION

OLD DOMINION UNIVERSITY
May 2020

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ABSTRACT

COMPARISON OF MOTOR-ENHANCED AND VISUAL-ENHANCED INTERVENTIONS FOR GRAMMAR IN YOUNG CHILDREN WITH DEVELOPMENTAL LANGUAGE DISORDER

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Old Dominion University, 2020
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Up to 7.6% of children demonstrate a developmental language disorder (DLD), which can persist through adulthood, causing difficulty with academic achievement, social relationships, and financial stability. Grammar development, as a hallmark of DLD, is an important area of need for these children. Existing grammar interventions do not clearly distinguish the sensory input techniques that meet these children's neurobiological instructional needs. This adapted alternating treatment design study implemented intervention using systematic paired visual and verbal and systematic paired motor, i.e. standardized gestures, and verbal sensory input techniques. A moderate-strong functional relation between intervention techniques using motor supports on grammatical outcomes in natural language practice (Tau-U = 0.68) and a potential functional relation between motor supports on grammatical outcomes in decontextualized tasks (Tau U = 0.45) were found. Both paired visual and verbal and paired motor and verbal interventions were found to have a potential functional relation with natural language use among children with DLD ages 4;7 – 6;9 years (n = 4). Patterns of response were reviewed in participants with comorbid delays in speech sound development, executive function development, and high activity levels. Children with severe grammar delays and ADHD/executive function challenges may derive more benefit from paired verbal and motor support. Children with milder overall language delays may respond better initially to combined

verbal and visual supports. Both intervention modalities were socially valid and provided

effectively by novice clinicians. Interventionists should consider conscious and consistent use of

different sensory techniques within grammar intervention for children with DLD.

This dissertation is dedicated to the children and graduate students under my care. Without them, this undertaking could not even have been started. I remain incredibly grateful to my family and my colleagues who managed to survive the experience with me.

ACKNOWLEDGEMENTS

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Introduction

In 2015, there were 1,332,000 children with primary speech or language impairments served in kindergarten through high school in public schools in the United States of America (United States Department of Education [USDOE], 2018). Language impairments often occur without corresponding difficulty articulating sounds in children ages two to seven years (Law, Boyle, Harris, Harkness, & Nye, 2000). A recent population estimate of school-age children with language impairment yields a prevalence rate of just under ten percent (Norbury et al., 2016). Some of these children will face difficulties in language skills that do not resolve completely (Law et al., 2000).

It should be noted that language impairment is a heterogeneous label, including oral and written language delays and disorders, as well as more narrowly defined impairments, such as specific language impairment, developmental language delay, and even dyslexia (Berninger & Wolf, 2016; Bishop, Snowling, Thompson, Greenhalgh, & Schiller, 2016). Thus, any review of literature which focuses on language impairment will encounter multiple terms that define difficulties within a multilevel language spectrum. The consensus term Developmental Language Disorder (DLD; Bishop, Snowling, Thompson, & Greenhalgh, 2017) is used throughout the rest of this document to refer to language impairment where no direct cause can be ascertained.

The impact of DLD can include limited achievement in literacy, resulting in academic underachievement, difficulties in peer relationships, and frequent bullying (Bishop et al., 2019; National Institute on Deafness and Other Communication Disorders, 2011). Children with DLD continue to manifest negative educational and post-academic outcomes. They have a significantly higher drop-out rate than age-matched typically developing peers (Hadley, 2004).

Young adults with DLD may also be significantly less independent in adult tasks of self-care, traveling, social interaction, and financial responsibilities (Conti-Ramsden & Durkin, 2008). DLD is present in up to 88% of young adults who are unemployed (Elliott, 2011) and 52% of adolescents who are incarcerated (Anderson, Hawes, & Snow, 2016). Even those young adults with DLD who report wellbeing similar to their typically developing peers may be more vulnerable to negative impacts of health, employment, and relationship challenges (Conti-Ramsden, Durkin, Mok, Toseeb, & Botting, 2016).

One of the most commonly prioritized instructional targets for children with DLD is grammar and syntax development (Kamhi, Nippold, & Hoffman, 2014). This priority reflects the viability of delayed grammar development, such as use of verb tense markers and sentence repetition skills, as diagnostic features for DLD (Pawłowska, 2014). Differences in grammar development can be tracked in children with DLD across time (Leonard, Haebig, Deevy, & Brown, 2017). Remediation of grammar tends to be difficult, and often fails to generalize (Hsu & Bishop, 2014). Also, difficulties in grammar tend to persist in verbal discourse, and appear in other domains, such as written language skills (Mackie, Dockrell, & Lindsay, 2013). Because grammar and syntax moderate the meaning of verbal utterances, appropriate grammar is necessary in order to effectively and meaningfully communicate. Children with DLD frequently require specific grammar intervention to do so.

Multisensory Inputs and Grammar Interventions

The importance of using hands-on, multi-sensory materials to help children learn was outlined by Maria Montessori over 100 years ago (Culclasure, Daoust, Cote, & Zoll, 2019). The provision of visual, auditory, tactile, and kinesthetic sensory inputs are common among interventions for children with learning disabilities (Farrell & Sherman, 2011). For the rest of

this document, the term *motor* will be used inclusively to refer to tactile and/or kinesthetic techniques, such as writing, drawing, or use of gestures. The potential for motor treatment techniques to benefit language recall and production has been demonstrated with both adults with acquired aphasia (Ferguson, Evans, & Raymer, 2012) and preschool children (Bedard, Bremer, Campbell, & Cairney, 2017). Evidence-based practice (EBP) in intervention for development of oral language include a range of different sensory techniques (Farrell, Pickering, North, & Schavio, 2004). For example, techniques such as drawing attention to the mouth of the teacher to support identification of specific sounds and identifying affixes within text to support understanding of meaning of the word are specifically visual inputs.

A brief review of existing studies which demonstrate successful grammar intervention reveals visual, verbal, and touch and motor cues ((Balthazar & Scott, 2018; Bredin-Oja & Fey, 2014; Calder et al., 2018; Curran & Owen Van Horne, 2019; Eidsvåg Sunniva et al., 2019; Feehan et al., 2015; Finestack, 2018; Hsu & Bishop, 2014; Kulkarni et al., 2014; Meyers-Denman & Plante, 2016; Owen Van Horne et al., 2017, 2018; Phillips, 2014; Plante et al., 2014; Ramirez-Santana et al., 2018; Shahmahmood Toktam et al., 2018; K. M. Smith-Lock, 2014; K. M. Smith-Lock et al., 2015; To Carol et al., 2015; Zwitserlood et al., 2015).

Visual support techniques described in existing grammar intervention studies include written stimuli or text for reference, such as To Carol et. al. (2015)'s use of text cards to cue production of conjunctions in sentences or discourse. Written or drawn production practice(Balthazar & Scott, 2018; Calder, Claessen, & Leitão, 2018; Curran & Owen Van Horne, 2019; Kulkarni, Pring, & Ebbels, 2014; Phillips, 2014; Ramirez-Santana, Acosta-Rodriguez, Moreno-Santana, del Valle-Hernandez, & Axpe-Caballero, 2018; Shahmahmood Toktam, Zahra, AliPasha, Ali, & Shahin, 2018; To Carol, Lui Hoi, Li Xin, & Lam Gary, 2015; Zwitserlood,

Wijnen, Weerdenburg, & Verhoeven, 2015)such as Curran & Owen Van Horn (2019)'s use of child-drawn experiments and adult priming for production of adverbial clauses were also noted. Meyers-Denman & Plante (2016) explicitly created specific visual cues to attend, such as positioning the clinician in the child's visual field before verbal recasting. Other techniques include using stimuli derived from the child's visual attention (Balthazar & Scott, 2018; Curran & Owen Van Horne, 2019; Hsu & Bishop, 2014; Owen Van Horne, Fey, & Curran, 2017; Phillips, 2014; Ramirez-Santana et al., 2018). The systematic use of colors, shapes, and lines, such as Calder et al.'s (2018) use of subject and predicate shapes and introduction of colored arrows to visually build complete tense-marked simple sentences occur, as well as picture representations of the semantic context of targets, such as Plante et al.'s (2014) presentation of uninflected verb forms in pictures from books or cards. The frequent use of picture and text stimuli and the use of self-generated visual materials suggest that visual techniques may be a valuable component of effective grammar interventions.

These same primary studies describe extensive use of auditory-verbal teaching and support techniques. Frequent techniques include oral instruction, oral target models, elicitations, and recasts, as well as systems of oral prompts. Oral stimuli may be provided by both computer (Balthazar & Scott, 2018; Finestack, 2018; Hsu & Bishop, 2014) and live clinicians (Bredin-Oja & Fey, 2014; Calder et al., 2018; Curran & Owen Van Horne, 2019; Kulkarni et al., 2014; Owen Van Horne, Curran, Larson, & Fey, 2018; Owen Van Horne et al., 2017; Phillips, 2014; Plante et al., 2014; Ramirez-Santana et al., 2018; Shahmahmood Toktam et al., 2018; To Carol et al., 2015; Zwitserlood et al., 2015)). Curren et al. (2018) provide a description of verbal teaching techniques provided within one language intervention session, including: multiple text models read with the student, deliberately elicited child utterances recast into the target structure, use of

target facilitative language (i.e., use of why questions to facilitate causal relationship terms), more adult elicited and recast utterances, and spontaneous adult models throughout the session. Auditory but non-verbal cues, such as a finger-snap or the sounding of a bell, are used infrequently to establish attention (Eidsvåg Sunniva, Plante, Oglivie, Privette, & Mailend, 2019; Meyers-Denman Christina & Plante, 2016). The use of auditory-verbal techniques within grammar intervention appears universal.

In contrast, teaching and support techniques involving touch and motor are unspecified in many of these same grammar intervention studies. Those techniques that were described included writing or drawing for production practice (Balthazar & Scott, 2018; Curran & Owen Van Horne, 2019; Kulkarni et al., 2014; Owen Van Horne et al., 2017; Ramirez-Santana et al., 2018; To Carol et al., 2015). Child-produced drawings and text, like those described above from Curran and Owen Van Horne (2019) provide touch and motor input as the child creates a visual representation for later use. Some intervention programs noted the use of touch cues to establish attention (Eidsvåg Sunniva et al., 2019; Meyers-Denman Christina & Plante, 2016), such as lightly touching the child's hand, arm, or shoulder. More embedded touch and motor techniques include movement of or pointing to visual cues (Calder et al., 2018; Zwitserlood et al., 2015), such as Zwitserlood et al.'s use of Lego® bricks to physically build sentence representations and re-enactment of targets in context (Owen Van Horne et al., 2017; Plante et al., 2014; Ramirez-Santana et al., 2018), such as Plante et al.'s play-based verb use.

Because they are less often documented than auditory-verbal techniques, professionals may assume that visual and motor techniques are less essential to effective interventions; however, this may not be true. Existing studies of interventions to improve grammar development in young children have not analyzed the multiple sensory components (e.g., visual,

auditory-verbal, or motor techniques). Thus, there is a need for further investigation of the impact of the use of specific sensory modalities within language intervention.

This study uses two different intervention techniques to increase the use of grammatical structures by children with DLD. Both intervention models used the auditory-verbal models present in existing empirical studies and clinical practice but differed in the paired sensory input provided. Specifically, verbal strategies were paired naturally with either a systematic visual support or a systematic motor support. The purpose of the study is to answer the following research questions:

1. Is there a functional relation between language interventions that pair verbal support with a) systematic visual or b) systematic motor with the use of grammatical structures by children with developmental language delay (DLD)?

2. Does the rate at which children with DLD learn grammatical structures differ between language interventions that pair verbal support with a) systematic visual or b) systematic motor?

3. Does the sensory modality pair used within language interventions impact the generalization and/or maintenance of use of grammatical structures by children with DLD?

Method

The current study consisted of a single-subject adapted alternating treatment study designed to compare treatment efficiency of paired visual and verbal interventions with paired motor and verbal interventions. The study was designed to meet the standards for single subject research within What Works Clearinghouse recommendations (WWC; 2017). Relevant non-

experimental variables, such as time of session and order of implementation, were counter-balanced (Sindelar, Rosenberg, & Wilson, 1985). The type of intervention provided first within the session was randomized within each participant, using random.org's coin flipper program (Haarh, 2019). No more than three sessions using the same implementation order occurred, to minimize order-of-presentation effects. The equivalence and independence of potential target grammatical structures was determined by synthesizing existing knowledge of those structures appropriate to children's developmental level with each participant's baseline performance. Further independence of targets was established through sampling data on a control structure, again of equivalent level of difficulty. The control structure consisted of a grammatical structure produced incorrectly by the child which was not targeted for intervention. The assessment of control structure production also allowed detection of maturational change, a potential threat to internal validity (Ledford & Gast, 2018).

Participants

Participants in the study included child participants, their parents or caregivers, and novice clinicians. The novice clinicians were graduate student clinicians in a University speech-language pathology program. Graduate student clinicians were self-identified volunteers, recruited through brief presentations in academic classes. Face-to-face meetings to discuss the study in more detail and present the Consent to Participate form were scheduled by email. Involvement or lack of involvement in the study did not impact the graduate student clinicians clinical or academic program success in any way. Participants were free to withdraw at any point, as participation was completely voluntary.

Recruitment and Identification. Child and parent participants were recruited through information flyers provided to area school districts via PeachJar marketing, direct distribution to

special education directors, and posted within community Facebook groups. Informed consent documents for both child and parent participants were presented to parents or caregivers following their initial contact with the researcher. These documents were reviewed in person at a mutually convenient time before the child participant completed any screening, assessment, or intervention sessions.

Sixteen potential participants were screened to identify at least three potentially equivalent grammatical errors by the Test of Early Grammatical Impairment (TEGI; Rice & Wexler, 2001). Target grammatical structures were confirmed with a language sample analysis, from a 50-utterance conversational or narrative sample. Initial targets were chosen as detailed below, by participant, based on those structures that were nonproductive, developmentally-appropriate, unimpacted by existing articulation errors, and likely to occur in the child's natural daily activities. Initial target structures for each participant, as described below, were then deliberately assigned so the intervention type varied when the same targets applied across participants.

Confirmation of DLD was completed for four child participants between 4;0 and 6;0 without existing language standard scores using the Clinical Evaluation of Language Fundamentals – Preschool, Second Edition (CELF-P:2). The CELF-P:2 was chosen as a comprehensive language instrument with better psychometric properties than other options for children in this age group (Denman et al., 2017). The single participant outside this age range completed the Clinical Evaluation of Language Fundamentals, Fifth Edition (CELF-5). Use of the two CELF instruments allowed direct comparison of composite scores. A composite score at least 1.0 standard deviations below norms on the appropriate test was required for inclusion in the study. Six potential participants were excluded due to expressive language at the single-word

level or below. Five potential participants declined further involvement in the study for various reasons, including transportation and time commitment. Five participants were identified as appropriate for the study. All five sets of parent participants provided consent for both the child participants and themselves. Participant 1, a six-year, six-month-old Caucasian male native English speaker, was withdrawn from the study in baseline phase as he did not maintain a stable baseline with any potential grammatical target. Due to the frequency with which children with DLD demonstrate comorbid diagnoses and difficulty with executive function, medical history was reviewed and the Behavior Rating Inventory of Executive Function (BRIEF) Parent form was also completed. The relevant demographic, communication, comorbid diagnosis, and executive function information for remaining participants are available in Tables 1, 2, and 3.

Insert Chapter 1 Table 1, Table 2, and Table 3

Participant 2. Participant 2 (P2) was a Caucasian five-year, five-month-old male with existing diagnoses of childhood apraxia of speech and expressive language delay. He spoke English with a standard dialect as his only language. His referring speech therapist indicated continuing difficulty with personal pronouns and copula production despite functional motor planning ability, as well as continuing difficulty with verb tense markers. Uncontractible copula and third person singular -*s* were nonproductive. Difficulties with irregular plurals and possessive pronouns were noted within limited spontaneous production opportunities. Areas of greatest challenge included third person singular -*s* and past tense. Stimulability indicated that P2 was able to produce /s/, /z/, /d/, and /t/ in words and sentences, meaning that allophones of some grammatical morphemes could be produced. Grammatical targets chosen included copula *be* verbs, possessive pronouns, and regular past tense. Following baseline probes to establish target equivalency, copula *be* targets were withdrawn due to higher comparative spontaneous

production. Third person singular -*s* was substituted, and assigned to the visual intervention condition for the duration of the study. Possessive pronouns were assigned to the motor intervention condition and regular past tense was the control structure.

Participant 3. Participant 3 (P3) was a four-year, seven-month-old African-American male with existing diagnoses of articulation disorder, mixed expressive-receptive language disorder, and attention deficit hyperactivity disorder. P3's family spoke English with a standard dialect and some community exposure to African-American dialect. Past tense verbs, copula *be*, auxiliary *be*, third person singular -*s*, regular plurals, possessive – '*s*, and pronoun case were nonproductive. Articulation assessment confirmed severe articulation delay, with inconsistent active phonological processes. Stimulability indicated that P3 was able to produce /s/, /z/, /d/, and /t/. Grammatical targets chosen included copula *be* verbs (specifically *was* and *were*), regular past tense, and *do* question inversion. *Do* question inversion was assigned to the visual intervention condition for the duration of the study. Regular past tense was assigned to the motor intervention condition and copula *be* was the control structure.

Participant 4. Participant 4 (P4) was a six-year, nine-month-old Asian female with existing diagnoses of articulation disorder secondary to cleft palate, attention deficit hyperactivity disorder, and expressive language delay. P4 had no exposure to her birth language past the age of approximately four months and was considered a native English speaker. Copula *be*, plurals, auxiliary *be*, and third person singular -*s* were nonproductive. Stimulability indicated that P2 was able to produce /s/, /z/, /d/, and /t/ with some distortion on fricative sounds. Grammatical targets chosen included copula *be* verbs, regular past tense, and *do* question inversion. Copula *be* statements were assigned to the visual intervention condition for the

duration of the study. Regular past tense was assigned to the motor intervention condition and *do* question inversion was the control structure.

Participant 5. Participant 5 (P5) was a four-year, eight-month-old Latino male with no previous diagnoses of communication disorders. He was a native English-speaker. His mother reported concern with both articulation and language expression. Past tense verbs, copula *be*, auxiliary *be*, third person singular -*s*, regular plurals, possessive – *'s*, and question inversion were nonproductive. Articulation assessment confirmed severe articulation delay, with inconsistent active phonological processes. Stimulability indicated that P5 was able to produce /z/ in the word /ɪz/ (*is*) but did not reliably produce /s/, /z/, /d/, and /t/ in other contexts. Grammatical targets chosen included copula *be* verbs (specifically *was* and *were*), regular past tense, and *do* question inversion. Following equivalency probes, copula *be* targets were withdrawn due to higher comparative spontaneous production. Relative clause production was substituted and assigned to motor intervention condition for the duration of the study. *Do* question inversion was assigned to the visual intervention condition and regular past tense was the control structure.

Graduate clinician participants. Five graduate student clinicians volunteered to participate in this study. Two of the graduate clinicians were within their third semester of on-campus practicum experience when the study began; they each had previous experience with one or two child clients. Three of the graduate student clinicians began this study as their first clinical experience; one of whom was in her first semester of on-campus practicum experience and two of whom had not yet begun clinical practicum. The graduate student clinician in her first semester of practicum, who was assigned to Participant 1, withdrew from the study at the same time as her child participant. Assignment of graduate student clinicians to child participants was completed based on mutual availability.

Baseline

Baseline phase consisted of a minimum of five twice-weekly 30- to 45-minute sessions within approximately three weeks scheduled at parent and child participant, graduate student clinician, and researcher availability. The total number of baseline sessions ultimately depended on the level and trend of the data. In each baseline phase session, child participants completed a 30-item probe task. Ten items for each of the individual's three targeted grammar structures were elicited without verbal, visual, or motor supports. The targets included the two assigned to intervention techniques, as well as a control structure. One model item and one practice item were presented before each probe, allowing clinicians to ensure their child participants understood the task. Probe items consisted of a picture illustrating a targeted grammatical structure within a sentence, and included a sentence starter, such as "In this picture, we see . . . ." Child responses were transcribed and scored for accuracy of the targeted grammatical structure. All probe items were presented in random order.

The second section of each baseline phase session consisted of two 15-minute play activities. The length of practice and number of activities was created to parallel intervention dosage. Each activity was designed to provide obligatory contexts for production of one target grammatical structure. No verbal, visual, or motor supports were provided within these activities; however, production data were recorded to track initial target acquisition within a naturalistic task.

Intervention

In the treatment phase, eight 30- to 45-minute intervention sessions were scheduled twice weekly over the course of four to five weeks. Total dosage provided was in line with existing literature in grammar intervention (Meyers-Denman & Plante, 2016; Smith-Lock et al., 2013)

and current practice (Finestack & Satterlund, 2018). The first intervention session continued the baseline probes. At the beginning of intervention sessions 2 through 8, a probe assessment of each participant's retention of the grammatical target was completed. Each probe assessed five treated contexts for each intervention target. The term treated context identifies an actual child production connecting the target grammatical structures with a specific vocabulary term, such as the word *cats* (targeting the plural marker). These probes measured the session-to-session learning of target grammar structures, or *retention*.

Following the retention probe, two intervention activities were completed. The first intervention activity targeted one of the chosen grammatical structures using either visual or motor intervention strategies, randomly determined. Efforts were made to include activities that were of interest to the participants, based on parent and/or child indications of preferred activities. Children were actively engaged in the play activities. The second activity targeted the second grammatical structure using the remaining intervention strategy. Procedures were parallel across the two activities; the only systematic difference was the treatment strategy. Elicited and spontaneous production data were recorded to track continuing target use within a naturalistic task. This data tracked the initial *acquisition* of target structures within a single session.

Intervention Protocol. Within the first intervention session, the graduate student clinicians introduced each intervention technique with a brief verbal script and demonstration, then guided each participant through one to three practice items, providing specific feedback to the child participant. This explicit instruction was repeated briefly at the beginning of each relevant activity within each subsequent intervention session. At the beginning of each activity, child participants were informed which intervention technique was to be used during that

activity. Clinicians selected activities that allowed at least ten opportunities to elicit each child's

grammatical structure(s).

Clinicians utilized implicit teaching procedures during each intervention activity to

prevent child participants from disengaging from the treatment session. These procedures

included repeated modelling of the target grammatical structure in the chosen intervention

technique. They provided indirect verbal cues, recasts, and direct mands to elicit at least ten

natural productions of the grammatical structure. Immediate feedback for both correct (e.g. I

like how you used your -*s* ending) and incorrect productions (e.g. Remember to use your good -*s*

ending) was provided. The type of feedback, including praise, expansion, and verbal cues for

repetition or corrected production, was determined in real time by the clinician as the most

appropriate to the child and natural to the situation.

Visual and Verbal Intervention. The paired visual and verbal independent variable used

the conventions of Shape Coding^{TM} (Ebbels, 2007), including the use of specific colors to

represent different parts of speech, arrows and underlines to represent tense and number, and

specific shapes to represent sentence structure. Relevant shape, color, and underline conventions

are illustrated in Appendix B. In this study, shapes were outlined and cut from neutral-colored

cardstock, then laminated for durability. Dry erase markers were used to add text for child

participants who read. Line drawings or photo cards could be placed within appropriate shapes

to represent correct use of specific vocabulary at the discretion of individual clinicians.

Clinicians presented or referenced the visual supports for each target production within

intervention activities. Children were permitted to use colored writing tools to create their own

shapes, arrows, and underlines as appropriate during craft activities.

Motor and Verbal Intervention. The paired motor and verbal independent variable used a systematic representation of grammatical structures through easily performed movements, or gestures. This motor component included both the sensation of motion (kinesthesia) and the touch where hand shapes met. This intervention was developed by the researcher, predicated on the idea that young children move and that motor patterns are associated with language development (Lavelli & Majorano, 2016), and with consideration of the existing literature. The intervention was designed to parallel the Shape Coding's systematic visual representations of grammatical structures through equivalent representational motoric actions.

Insert Chapter 1 Figure 1

Specific motoric actions for this study were developed from an established grammatically-representative motor code, i.e. Signing Exact English (Gustason & Zawolkow, 1993). In the proposed study, clinicians completed the motoric actions associated with each target production within intervention activities. For example, the clinician would say "The dinosaur walk<u>ed</u> away" while using the motor action for past tense as the regular past tense morpheme *-ed* was produced. Children were encouraged to supplement verbal target productions with these motor movements. Maximal range of motion was modelled and elicited in each movement.

Maintenance and Generalization

Retention in maintenance was assessed in 45- to 60-minute sessions, two held on the established twice-weekly schedule immediately following the intervention phase and one session each at two, four, and six weeks post-intervention. These sessions paralleled the child's intervention experience thus far. A brief statement encouraging participants to use their special color and motor words was provided at the beginning of each session, i.e. "Remember, you can

use your special words so I understand you." No further practice, details, or reminders were provided. A 10-item probe of treated contexts from throughout the intervention sessions assessed retention of target structures at the beginning of each maintenance assessment. The two alternating activity blocks were duplicated without feedback or cues to correct production. Production data were recorded to track target maintenance of overall learning within a naturalistic task.

Following these activities, the initial probes, which contain vocabulary contexts that had not been included in the intervention phase, were re-administered to serve as a generalization measure. A language sample using the current SUGAR procedures (Pavelko & Owens Jr, 2017, 2019) was collected within the final maintenance session to further assess generalization. The productivity of control, motor intervention, and visual intervention structures was determined. Productivity is reported as a percentage created by the number of correct grammatical structures spontaneously produced divided by the number of grammatically-mandatory contexts included within the sample. Generalization of improvement into functional expressive language was captured with the percentage of productivity of target features and general improvement in expressive language measures, including Total Number of Words (TNW), Mean Length of Utterance (MLU_S), Words Per Sentence (WPS), and Clauses Per Sentence (CPS) were documented on both initial and final language samples for each child participant. The general measures were converted to *z*-scores using norms from the SUGAR procedure to allow comparison of changes.

Data Analysis

All study sessions from initial screenings through maintenance were audio- and video-recorded for review and verification of data. Data analysis was intended to be comprehensive,

providing clear descriptions of data through both visual analysis and statistical modelling. Visual analysis served as the primary evaluation tool for the results of both probe data and acquisition data, and included level, trend, and phase change comparisons from each study phase (Horner, Carr, & Halle, 2005; Ledford & Gast, 2018). Data level stability was measured with a 20% envelope criterion based on median value (Ledford & Gast, 2018). To aid in interpretation, Tau-U effect estimates were generated from nonparametric statistical analysis of the data completed in accordance with Parker, Vannest, Davis, and Sauber (2011), using the Tau-U calculator application (Vannest, Parker, Gonen, & Adiguzel, 2016). Tau-U was appropriate as a comparison statistic due to its compatibility with visual analysis and its ability to account for level change across phase and positive baseline trends. Effect sizes were predetermined such that a score lower than or equal to 65 represented no or mixed effect, a score between 66-92 represented a clear effect, and a score greater than 93 represented a strong effect (Rakap, 2015).

Results

Participant 2

P2 began baseline sessions with a motor structure target of copula *be,* a visual structure target of third person singular *-s*, and a control structure of regular past tense. While visual and control structures demonstrated equivalency and either stable data or flat trend, the motor structure demonstrated a steady and ascending trend during baseline. Thus, an alternate motor target of nominal possessive pronouns was substituted, and baseline was conducted with the new target.

Acquisition. P2's use of motor and visual structures within play activities was tracked throughout baseline, intervention, and maintenance phases. During the intervention phase, his clinician actively supported the use of the target structures. Within targeted play, motor target

mean accuracy improved between baseline and intervention phases. Production in maintenance phase continued to improve. A ceiling effect was evident in intervention and maintenance phases. Visual target mean accuracy also improved between baseline and intervention phases. Production in maintenance phase continued to increase in accuracy. Notably, data variability decreased significantly from baseline through maintenance phases for both target structures. No significant change in accuracy or variability was noted on the control structure, i.e. change was well within a standard deviation of the baseline mean. P2's acquisition data are available in Table 4 and Figure 2.

<div style="text-align:center">Insert Chapter 1 Table 4</div>

<div style="text-align:center">Insert Chapter 1 Figure 2</div>

Retention. Following baseline, P2 completed retention probes of treated contexts for motor and visual targets in both intervention and maintenance phases. His production of his targeted motor structure demonstrated improvement from baseline with a two-session delay and a clear ascending trend throughout the intervention phase. This level of production was maintained through two weeks of maintenance but demonstrated a rapidly descending trend at the four- and six-week sessions. A ceiling effect was evident at the end of the intervention and beginning of maintenance sessions with this target. P2's production of his targeted visual structure demonstrated a small immediate effect with extremely variable data throughout the intervention phase. Intervention ended with a shallow descending trend. Level of production was maintained through two weeks of maintenance but demonstrated a rapidly descending trend at the four-week session. Production during the four- and six-week maintenance sessions was equal to that of the first three baseline sessions. Data from P2's retention probes are available in Table 5 and Figure 3.

Insert Chapter 1 Table 5

Insert Chapter 1 Figure 3

Generalization. P2 completed generalization probes in untreated contexts for motor, visual, and control targets in baseline and maintenance phase. Motor and visual target mean accuracy improved substantially, although visual target overall mean was slightly lower than motor. Slight accelerating trends throughout the maintenance phase were noted. No significant change was noted on the control probe, i.e. change was well within a standard deviation of the baseline mean. P2's data are available in Figure 4.

Insert Chapter 1 Figure 4

Functional Use. P2's initial language sample included seven attempts at his visual target structure of third person singular -*s*. He correctly produced five of those, for an initial percentage of 71% correct. In his final language sample, he spontaneously generated five attempts which were produced with 100% accuracy. Initially, P2's generated two attempts at his motor target structure of nominal possessive pronouns. These were produced with an overall accuracy of 100%. P2's final language sample demonstrated a continued accuracy of 100% with a minimal increase to three attempts. P2's initial language sample demonstrated minimal but correct use of his control structure, regular past tense, i.e. 100% accuracy in two opportunities. During his final language sample, P2 maintained 100% accuracy in 12 spontaneous generations. Changes in functional use are available in Table 6.

Insert Chapter 1 Table 6

Generalized Language Improvement. Overall language statistics were also recorded pre- and post-intervention. These are available in Table 7. P2 maintained stable scores in Total Number of Words (TNW), Mean Length of Utterance (MLU$_S$), and Words per Sentence (WPS).

P2 demonstrated an increase in Clauses Per Sentence (CPS) well over the standard deviation for his age group.

<div align="center">Insert Chapter 1 Table 7</div>

Participant 3

P3 began with a motor target of regular past tense *-ed*, a visual target of *do* question inversion, and a control structure of copula *be*.

Acquisition. P3's use of motor and visual structures was tracked throughout baseline, intervention, and maintenance phases within play activities. During the intervention phase, use of the target structures was actively supported. Within targeted play, motor target mean accuracy improved between baseline and intervention phases. Production in maintenance phase declined slightly but remained within the stability envelope. Visual target mean accuracy improved between baseline and intervention phases. Visual production in maintenance phase declined. Data were variable throughout all phases of the study. Production of P3's control structure improved from baseline to intervention and further within maintenance. P3's acquisition data are available in Table 4 and Figure 2.

Retention. Baseline production for both motor and visual targets in probes were stable at 0% accuracy. Baseline production for the control structure, copula *be,* demonstrated a declining trend with overall low accuracy. Following baseline, P3 completed treated context probes. No change in visual structure production was noted. Change in motor structure production began at the fifth intervention session and demonstrated a highly variable accuracy with an overall ascending trend throughout the intervention phase. Production accuracy peaked at the second maintenance session, three weeks post-intervention, then declined precipitously at both four and six weeks. P3's retention data are visually available in Table 5 and Figure 3.

Generalization. P3 completed generalization probes of untreated contexts for motor, visual, and control targets in baseline and maintenance phase. Motor and visual target production remained at a flat 0% accuracy throughout the study. No significant change was noted on the control probes, i.e. change was well within a standard deviation of the baseline mean. Data from P2's generalization probes are available in Figure 4.

Functional Use. P3 attempted seven productions of his visual target structure regular past tense within his initial language sample. None were produced correctly. In his final language sample, P3 attempted five regular past tense verbs and achieved an improved accuracy of 60%. In his initial language sample, P3 made four unsuccessful attempts at his motor target structure of inverted question formation, although all added a *wh-* question word, e.g. "Look, where his head?" In his final language sample, P3 achieved 50% accuracy on two attempts at inverted questions. The first attempt used a *wh-* question and was incorrectly formulated, e.g. "What that is the green playdough?" The second production matched the format of his specific targeted question inversion, and was produced correctly, e.g. "Are you calling somebody?" Initially, P3's generated ten attempts at his control target structure of contracted and uncontracted copula *be*. These were produced with an overall accuracy of 70%, with a stark division between them: contracted *copula be* was 0% correct, while uncontracted copular *be* was 88% correct. P3's final language sample demonstrated an overall accuracy of 53%. Uncontracted copula *be* was 43% correct and contracted copula was 100% correct. Changes in functional use are available in Table 6.

Generalized Language Improvement. Also, overall language statistics were recorded pre- and post-intervention using data from language samples. These are available in Table 7. P3 maintained scores within one standard deviation of his initial measurements in TNW and MLU$_S$,

while WPS and CPS increased beyond one standard deviation. Although the TNW and MLU$_S$ did not improve a complete standard deviation, both changes brought P3's scores within the average range for children his age. The changes in WPS and CPS were even greater. At the post-intervention language sample, both scores were within average norms of performance for children his age.

Participant 4

P4's target motor structure was regular past tense -*ed*. Her visual target structure was copula or auxiliary *be* statements. Her final control structure was *do* question inversion.

Acquisition. P4's accuracy of motor and visual target production within play-based activities was tracked through all three study phases. Both structures demonstrated a clear and immediate intervention effect. These data reflect a notable decrease in variability within the intervention period. Although variability again increased and a clear decrease in accuracy was evident in P4's third maintenance session (three weeks following intervention), her accuracy rebounded, such that overall trendlines were positive for both structures. Mean production accuracy in maintenance remained higher than baseline for motor and visual structure use. The acquisition activity data for P4 are available in Table 4 and Figure 2.

Retention. During the baseline phase, both motor and visual accuracy data demonstrated high variability and decreasing trends. Change in intervention was on a consistent two-session delay with high production variability. Overall motor structure accuracy demonstrated a shallow decreasing trendline while overall visual structure accuracy demonstrated a shallow increasing trendline. In maintenance, both motor and visual structure production accuracy was variable, but retained at mean levels equivalent to baseline. Control structure accuracy was stable with lower variability. P4's retention data are available in Table 5 and Figure 3.

Generalization. P4 completed generalization probes of untreated contexts for motor, visual, and control targets in baseline and maintenance phase. Although both motor and visual target accuracy was highly variable, motor structure mean accuracy remained consistent from baseline, while visual target mean accuracy decreased marginally. This level of change is within a standard deviation of the starting level. Performance on the control probe also decreased. P4's data are available in Figure 4.

Functional Use. Initially, P4 generated 17 attempts at copula and auxiliary *be*. These were produced with an overall accuracy of 24%, with a stark division between them: copula *be* was 0% correct, while auxiliary *be* was 57% correct. P4's final language sample demonstrated an overall improvement of accuracy with changes to copula *be* accuracy leading the improvement. This level of accuracy was demonstrated over 22 attempts, representing a relatively stable number of attempts at this structure. P4's initial language sample demonstrated minimal but correct use of her motor structure target of regular past tense, i.e. 100% accuracy in only one opportunity. During her final language sample, P4 maintained 100% accuracy in two spontaneous generations. P4's initial language sample also included one spontaneous attempt at her control structure of *do* question inversion. She used it correctly, for an initial percentage of 100% correct. This performance was replicated in her final language sample. Changes in functional use are available in Table 6.

Generalized Language Improvement. Overall language statistics were also recorded pre- and post-intervention based on the language sample analyses. These are available in Table 7. P4 celebrated her seventh birthday during the intervention study, such that her scores were compared to norms for age group 6;6 – 6;11 during her initial LSA and to those of the age group 7;0 – 7;11 during her final LSA. Thus, although her raw scores increased in half of the

measurements, her performance relative to her peers was variable. P4 maintained stable *z*-scores in TNW, MLU$_S$, and CPS, while WPS demonstrated a notable decrease. The absolute change in WPS from 6.03 words to 5.45 WPS represents a *z*-score change of -1.39, indicating a significant decrease in comparison to peers.

Participant 5

P5 began baseline sessions with a motor structure target of copula *be*, a visual structure target of subject tense pronouns, and a control structure of regular past tense. Initially, production of the motor structure demonstrated a clear ascending trend. Alternate motor targets of equivalent developmental level, such as plurals and third person singular -*s* were considered and probed, but due to this client's significant difficulty producing fricative sounds, the use of relative clauses was ultimately chosen as a substitute target. P5 proved responsive to the initial probe following grammatical priming and the baseline phase was repeated successfully, although with notable production variability.

Acquisition. P5's baseline, intervention, and maintenance phase production of target structures were tracked within play activities. During intervention phase, use of the target structures was actively supported. Within targeted play, motor target mean accuracy improved between baseline and intervention phases. Production accuracy in the maintenance phase decreased slightly, but mean accuracy remained stable with the intervention mean. Visual target mean accuracy also improved between baseline and intervention phases. Production in maintenance phase declined slightly, but mean accuracy remained stable with the intervention mean. Data variability was significant within the intervention phase for both target structures, while production in baseline exhibited a slight accelerating trend with the motor intervention. After the two-session delay in response to motor intervention, like other child participants, a

sharp accelerating trend during intervention appeared. No overlap existed between baseline and intervention data points. Visual intervention demonstrated an immediate sharp accelerating trend. Production of P5's control structure decreased from baseline to intervention and stabilized through maintenance. P5's acquisition data are available in Table 4 and Figure 2.

Retention. Following baseline, P5 completed retention probes of treated contexts for motor and visual targets in both intervention and maintenance phases. Due to clinician error, no treated context was probed for P5's motor structure in maintenance session 4. His intervention-phase production of the targeted motor structure demonstrated continued variability and no improvement from baseline. In contrast, his production of the visual target demonstrated both increased variability and increased accuracy, with a steeply ascending trend. Despite the missing data point in maintenance, immediate and stable improvement of motor target production was noted. P5's ascending visual structure trend continued through the maintenance phase. Retention data for P5 is available in Table 5 and Figure 3.

Generalization Probe. P5 completed generalization probes of untreated contexts for motor, visual, and control targets in baseline and maintenance phase. Motor and visual target mean accuracy improved with a clear significant shift between phases. No significant change was noted on the control probe, i.e. change was within a standard deviation of the baseline mean. P5's data are available in Figure 4.

Functional Use. Due to the difficulty of creating opportunities for all of P5's target structures within a single language sample activity, spontaneous generation attempts were limited at both pre- and post-intervention administration. P5's initial language sample did not include any attempts at his visual target structure of subject tense pronouns. In his final language sample, he spontaneously generated two attempts, which were produced with 100% accuracy.

Initially, P5 did not generate any attempts at his final motor target of relative clauses marked with the copula phrase *that is*; however, he did demonstrate two incorrect attempts at a simple copula phrase. P5's final language sample demonstrated improvement in overall accuracy for simple copula *be*; however, P5 did not attempt production of the targeted relative clause. P5's initial language sample demonstrated no attempts at his control structure, regular past tense. During his final language sample, P5 he spontaneously produced two attempts of his control target with 50% accuracy. Changes in functional use are available in Table 6.

       Generalized Language Improvement. Overall language statistics were also recorded pre- and post-intervention. These are available in Table 7. P5 demonstrated significant improvements in all measured statistics: TNW, MLU_S, WPS, and CPS.

Group Data Analysis

       Effect size estimates were created using the Tau-U calculator application (Vannest et al., 2016). Effect sizes were generated for retention data during baseline and subsequent treated contexts, as well as for acquisition data across baseline and subsequent phases. Baseline correction was completed as appropriate. Following baseline trend corrections and phase contrasts, the weighted average Tau-U scores across participants were judged by standards provided above. Motor retention data yielded a Tau-U of 0.4501 ($p = 0.0029$), while motor acquisition data yielded a Tau-U of 0.6822 ($p < 0.0001$). Visual retention Tau-U was calculated at 0.3095 ($p = 0.0351$) and visual acquisition Tau-U at 0.5939 ($p < 0.0001$). Control retention Tau-U was -0.0485 ($p = 0.7955$) and control acquisition Tau-U was -0.4208 ($p = 0.0051$). As expected, mixed or no effect was found within both control contexts. Motor and visual retention data yielded no clear effects. A clear positive effect was evident for the motor intervention in

acquisition tasks, when intervention took place during functional activities. The Tau-U value for visual acquisition approached, but did not meet, the criterion for clear effect.

Implementation Fidelity

Implementation fidelity of procedures were assessed in 40% (2/5) of randomly-selected baseline probes, 37% (3/8) of intervention activities, 43% (3/7) of intervention retention probes, 40% (2/5) of maintenance retention probes, and 40% (2/5) of generalization probes.   Due to a combination of researcher error and technological failure, recordings from five of the total 72 sessions were unable to be archived. These include P2's intervention session 6, P3's intervention session 7, P4's maintenance session 3, and P5's intervention session 5 and maintenance session 2. These missing sessions were omitted from the total pool when sessions were randomly selected for implementation fidelity coding. Each graduate student clinician committed to observe and code their peers' fidelity in all phases of the study. Sessions were assigned randomly, and fidelity was measured on a point-by-point checklist of required components for each phase and task. Additional fidelity ratings were provided by the researcher and trained research assistants. Research assistants, graduate and senior undergraduate students in speech-language pathology, received one hour of guided practice coding implementation fidelity, and point-by-point agreement greater than 90% was achieved on a practice coding session before study coding began. Overall, study fidelity was measured at 85% (range = 65% - 95%). Analysis of the total and across-phase fidelity is available in Table 8. Intervention type demonstrated less than 1% difference in fidelity between visual and motor interventions. Order of activity demonstrated less than 3% difference in fidelity between first and second presentations. Therefore, no significant difference was noted due to order of activity or intervention type.

Insert Chapter 1 Table 8

Social Validity

Social validity data were gathered from both parent and graduate student participants by questionnaire on the final maintenance session of the study. Items were rated on a 5-point Likert scale, with 1 = Strongly Disagree and 5 = Strongly Agree. In general, parents strongly agreed that their child benefitted from the intervention. They did not appear to specifically notice if their children used motoric actions (i.e. the assigned gestures) to produce grammar structures (average score = 3) and were slightly more confident that the children referenced the visual intervention's shapes and colors (average score = 3.6). Parents agreed that their child's grammar production improved overall (average score = 4.4), that they would recommend specific visual or motor grammar intervention (average score = 4.8), and that they would like to learn more about the interventions provided (average score = 4.5). Two of the four responding parents indicated that they preferred the visual intervention modes because their children referenced them more often than the motor intervention. One parent reported no preference between the interventions and did not indicate a reason for their ambivalence. One parent indicated that they preferred the tactile intervention mode because it was easy to do and required no special equipment. This parent also noted that their child does better with active therapies.

Graduate student participants unanimously agreed that their child participants benefitted from the intervention (average score = 4.0) but were slightly less confident that grammar specifically improved (average score = 3.3). Their clients were reported to use both intervention modalities (average score = 3.7), although there was higher variability in reporting the client use of gestures (range 2 – 5) than shapes and colors (range 3 – 4). One clinician specifically noted that although the client's mother reported the client's spontaneous use of the visual intervention

techniques at home, he was observed spontaneously using the motor actions for self-correction in his final maintenance session. Two of three responding graduate student participants preferred the tactile-kinesthetic intervention. One of these noted that it was easier for her to provide the visual shapes and that her child participant would refer to them, but that as the interventions continued, the child participant used motor actions more frequently. The other clinician who preferred tactile-kinesthetic interventions referenced her client's level of activity and enjoyment of movement. She indicated a belief that the most effective therapeutic "modality is client dependent."

Graduate student participants agreed that they ended the study feeling confident in their ability to provide intervention for grammar challenges (average score = 4.3). They were more confident that they had learned appropriate methods for doing so (average score = 4.7) and would use what they had learned again (average score = 4.7). They all strongly agreed that participation in the project was worth their time and effort (average score = 5). One participant expressed gratitude for the opportunity to participate, indicating that it had been an enjoyable clinical experience. Another reiterated the value of the techniques learned and noted additional clinical learning in flexibility through the study experiences.

Reliability

To enhance the trustworthiness and confirmability of data collected, randomly-determined sessions were coded for reliability. Sessions missing due to technology challenges were simply omitted when sessions were randomly selected for coding. The first observer was the graduate student participant, who collected data on her assigned participant during real time within the study sessions. The researcher or a trained research assistant served as second observer and collected data from video recordings of sessions for each participant. Research

assistants, graduate or senior undergraduate students in speech-language pathology, received one hour of guided practice coding data, and point-by-point agreement greater than 90% was achieved on a practice coding session before study coding begins. To meet WWC guidelines, inter-observer agreement was assessed on at least 20% of each phase with each participant, specifically 40% (2/5) of baseline probes, 37% (6/16) of intervention activities, 43% (3/7) of intervention retention probes, 40% (2/5) of maintenance retention probes, and 40% (2/5) of generalization probes. Inter-assessor agreement was assessed statistically for consistency with intraclass correlations derived from the percentage of grammatical targets correct in acquisition as well as retention data. The final ICC value was computed at 0.90, indicating reasonable reliability for a clinical study (Trevethan, 2017).

Discussion

Intervention Effects

A clear moderate functional relation between intervention and outcome was confirmed in motor acquisition activities. Thus, practice in age-appropriate activities using verbal and systematic motor supports caused a positive outcome in grammar production. However, statistical analysis also supports the limited functional effects in visual acquisition activities. Thus, a smaller positive effect was caused by practice in age-appropriate activities using verbal and systematic visual supports. Similar limited functional impact was supported in motor retention learning. Thus, target structure learning carried over into later structured probes of practiced contexts. The outcomes for visual and motor intervention outcomes are notably different from those of control structures. Control structures showed no improvement in acquisition activities across participants and no improvement for three of four participants in percentage of accuracy during natural language use. Overall, there appears to be a moderate-to-

strong functional relation between intervention and daily use of more expressive language and more complex grammar among the group of participants.

Results from the current study align with many outcomes in the existing literature. For example, retention outcomes of P2 and P4 are consistent with the results of similar interventions using Shape Coding[TM] (Kulkarni et al., 2014), whose two participants demonstrated improvement within the intervention phase with significant effects sizes only being reached at the end of 10 weeks of treatment. The success of a multiple modality intervention that included tactile and motor stimuli replicates the success of MetaTaal, a Lego brick-based intervention (Zwitserlood et al., 2015). Zwitserlood et al. (2015) suggested that such interventions, which reduce the literacy demands upon children, can be more available to children with language impairments who often have literacy difficulties as well. The success of the current interventions supports this statement, as neither Shape Coding[TM] nor the systematic motor actions (i.e., gestures) developed for this study required literate sound-symbol knowledge. Instead, they both reflected the phonemic production of targeted grammar structures. Combinations of phonology and morphosyntactic interventions have been reported to be successful for expressive communication improvement in another small n study (Feehan et al., 2015). Control structure results in this study confirm that children do not improve response accuracy or functional use of morphological structures not specifically targeted (Eidsvåg Sunniva et al., 2019; K. M. Smith-Lock et al., 2013).

Intervention Modality Impact

This section addresses the rate at which children with DLD learn grammatical structures and the maintenance and generalization outcomes and compares them between language

interventions that pair verbal support with a) systematic visual or b) systematic motor. Visual and motor acquisition and retention outcomes were analyzed to gather information.

   Speed of Learning. The first aspect considered was the speed of learning, or how soon in the intervention phase acquisition or retention data crossed the average baseline value for each participant. Motor acquisition data crossed the mean baseline value in the first intervention session for all participants (average = 1.00 sessions). Visual acquisition data generally crossed the mean baseline value in the first intervention session (average = 1.25 sessions). Motor retention data generally crossed the mean baseline value by the third intervention session (average = 3.50 sessions). Visual retention data crossed the mean baseline value in the second intervention session (average = 2.00 sessions), but one participant never improved visual retention beyond baseline.

   Magnitude of Learning. A second analysis was the magnitude of change. Change from highest baseline point to highest intervention point and average change across baseline to intervention phase were both reviewed. Motor acquisition outcomes demonstrated a highest point change of 69.5% (P3) and an average point change of 40.3%. Visual acquisition outcomes demonstrated a highest point change of 85.0% (P3) and an average point change of 46.4%. Motor retention outcomes demonstrated a highest point change of 40% (P3) and an average point change of 10.7%. Visual retention outcomes demonstrated a highest point change of 20.8% (P5) and an average point change of 8.0%.

   Maintenance and Generalization. Most child participants maintained both motor and visual acquisition accuracy in the maintenance phase; half of the child participants continued improvement in motor retention outcomes throughout the maintenance phase. Only one child demonstrated continued improvement in visual retention outcomes in that phase. In probe tasks

of generalization, half of the child participants demonstrated improvement with both their motor and visual target structures. In natural language tasks of generalization, all four participants improved either their percentage of accuracy or their number of attempts at targeted motor structures, as well as their percentage of accuracy for targeted visual structures. Half of child participants also increased their number of attempts at targeted visual structures.

Conclusion. Generally, both motor and visual acquisition outcomes were faster and greater than those obtained from retention probes. The slightly greater magnitude of learning from visual intervention methods falls within the standard deviation of the scores; the slight advantage in speed of learning from motor intervention methods is also negligible. There is also no difference in rate of learning between sensory modalities in retention in treated contexts. Thus, using paired verbal and systematic motor interventions may result in better rate of learning for production in natural activities. This benefit is unlikely to appear in drill contexts, such as probes.

Based on this analysis, maintaining improvement in contextualized practice does not depend on the sensory modality of intervention. However, continuing improvement and generalizing improvement in decontextualized tasks are slightly more likely when using motor sensory intervention supports. This pattern of learning was also reported within two studies where continuing improvement and generalization were demonstrated from a complexity-based intervention for morphological development (Owen Van Horne et al., 2018, 2017).   Children with lower executive functioning abilities may also be more receptive to motor supports. Improvement in functional use is more likely when using visual sensory intervention supports, particularly with children who are more mildly impaired.

This study is the first to directly compare visual outcomes and motor outcomes. In natural activities, a slight learning advantage to paired verbal and systematic motor supports is suggested. This is important for ultimate outcomes with children with DLD, particularly in view of the findings of Hsu & Bishop (2014), which indicated that memory span predicts grammar learning for these children. The visual and motor maintenance outcomes of this study also demonstrate differentiation by level of executive functioning and ADHD diagnosis. It is worth noting that participants sharing an ADHD diagnosis experienced clear difficulty in generalizing the use of the target structures in decontextualized tasks, e.g. probes. This implies that the use of decontextualized tasks for assessment may not reflect the true functional learning of students with ADHD. However, production accuracy continued to improve, and outcomes were mitigated when systematic motor interventions were used. Another logical conclusion is that younger students, particularly those with lower language and lower overall executive skill function may see more benefit from interventions that include systematic motor learning techniques than those with only verbal and visual supports.

The question of mechanism for the slight advantage of naturally paired verbal and motor supports remains. Research by Hilliard (2016) demonstrates that hand gestures have a direct impact on the neurological mechanism of memory. Hostetter & Mainela-Arnold (2015) note that gestures may communicate knowledge that is understood, but not yet linguistically encoded. Because automatic task performance may depend upon psychomotor abilities (Hubert et al., 2007), the use of motor as an intervention may supplement emergent linguistic knowledge to reduce task demands on children with DLD. Certainly, the results of Toumpaniari et al. (2015)'s study of vocabulary learning with natural and systematic gestural representations also supports the positive impact of interventions including a motor component.

As a final note, the results of this study suggest that the planned and consistent use of contextualized tasks, e.g. natural speaking activities, may have a positive impact on generalization of targets and generalized language improvement in both productivity and grammaticality. The use of natural language activities for systematic skill practice is in accordance with the evidence-based suggestions made by Kamhi et al. (2014). The incorporation of variable contexts is inherent within consistent use of natural practice opportunities. Use of variable individual targets within consistent target structures is supported for learning throughout the motor learning literature and supported within some language learning studies (Owen Van Horne et al., 2017, 2018).

Intervention Validity

Ease of Implementation. Three of four graduate clinician participants achieved an average fidelity greater than 84% across phases of these interventions. The graduate clinician participant with the lowest scores was able to maintain a 73% average across phases. This graduate clinician was paired with child participant P4. It is possible that P4's lack of improvement in retention and generalization probes and limited improvement in acquisition and natural language tasks results from her clinician's lower implementation fidelity. It may also be of note that this was the treating clinician's first clinical experience and the child participant had a severe articulation delay related to a repaired cleft palate, demonstrated severe expressive language delays, and had a diagnosed attention deficit hyperactivity disorder. Most clinicians will agree that this is a challenging client for any first-time clinician.

Fidelity can also be judged within only the critical intervention phase. Here, the graduate student clinicians yielded an average of 90%, the highest fidelity percentage by phase. The most common error in procedure was forgetting to thank the child for his or her effort during the

session. As most participants demonstrated moderate-to-strong improvement in grammar use during natural communication, it appears that 90% fidelity is sufficient to demonstrate improvement across an 8-session intervention. Therefore, while each graduate clinician participant could continue to improve, as a group, they implemented both interventions with adequate fidelity.

   Intervention Value to Clinicians. The novice clinicians who participated in this study felt strongly that learning the paired support techniques were beneficial to both their child participnts and themselves clinician directly. All responding graduate student participants agreed that they learned appropriate intervention techniques and feel confident in their treatment of impaired grammar. One commented that she also learned how to be flexible in session scheduling, while another appreciated the first-hand observation of research design and completion.

   Intervention Value to Parents. Parents clearly saw value in the intervention program. Two of four responding parent participants preferred the visual intervention supports while one preferred the motor supports. Their preferences seemed to directly reflect which type of support they saw their child using at home. However, it should be noted that the parent who preferred the motor-based supports was the only parent who observed the treatment sessions through live-time video observation. The other parents were not trained in recognizing systematic gestures. Their preferences for visual intervention supports may simply reflect the familiarity of shapes and colors.

   Conclusions. Both the existing Shape Coding™ and the new systematic motor interventions appear viable for more widespread use. While individual novice clinicians did not reach full fidelity to the intended intervention procedures, as a group, they implemented both

interventions with adequate fidelity. The clinicians also saw value in both types of interventions and speculated on the potential power in combining visual and motor intervention methods. Parents also reported value to both types of interventions and agreed that they benefitted their child and improved his or her grammar use.

Limitations of the Study

Single subject research designs allow demonstration of causality but are limited in ability to identify differences between individual participants vs differences generalizable to the general population. This is true of the current study. Therefore, any conclusions drawn about individual participant characteristics and the intervention outcomes will benefit from confirmation. The close attention to participant characteristics of comorbid disorders and relative severity enables the reader to understand the specific combinations of child characteristics and potential outcomes of both intervention types. Child executive function abilities were measured in this study with the BRIEF. Although the BRIEF is a valid and reliable measurement tool, it relies on parent report and may not reflect underlying neurological realities. Currently, there are few ways to directly measure the executive function abilities for young children. This lack may impact outcome interpretation. There is a corresponding difficulty quantifying comorbid diagnoses which may also impact interpretation. The current study addressed this by combining the severity levels of language impairment, as designated by standardized assessments, with subjective determinations from both graduate clinician participants and the researcher. Although attempts were made to reduce the impact of measurement limitations, there is no way to truly know their effect.

Other limitations became obvious throughout the course of the study. First, all results should be interpreted with caution in view of the relative nonresponse in Participant 4. In the

case of P4, her parent confirmed self-correction of targets at home. Both the researcher and the graduate student clinician felt that P4's difficulty with sustained attention may have limited her response to both interventions. Therefore, her intervention was modified to include the combined use of motor, visual, and verbal interventions and continued, with parent permission. This modified study has not been completed and the results will be reported in a future manuscript. A further threat to reliability and implementation fidelity was data loss due to malfunctions in the technology used to record intervention sessions. This threat was mitigated by completion of the planned percentage of second codings by substituting randomly selected sessions. The number and type of outcome measurements, which included immediate learning, delayed recall in both probes and natural activities, as well as specific and generalized language improvement, significantly added to the complexity of clear documentation and interpretation. Close review of existing literature was completed to allow comparison to similar outcome measures. Finally, unknown sources of error may have had unknown effects on the study outcomes.

Implications for Educational Practice

The original purpose for this study was to provide guidance for interventionists addressing grammar learning in children with DLD. Educators and related service personnel should note the importance of assessing the value of individual and combined sensory supports. Different children may benefit from different modes of support. However, interventionists can be confident that they should combine implicit and explicit methods of instruction and practice in natural contexts for skill generalization (See **Intervention *Procedures*** above for information about these methods in this study). The findings of this study also suggest that children with severe grammar delays and ADHD/executive function challenges may derive more benefit from

paired verbal and motor-based supports, such as gestures. Children who demonstrate milder overall language delays may respond better initially to combined verbal and visual supports. In any intervention, different sensory modes of support implemented inconsistently or without conscious intent may create unexpected impacts on potential outcomes. Thus, interventionists, such as teachers and related service providers, need to be considerate in intervention implementation.

Suggestions for Future Research

Needs for further research are evident from the discussion of the current study. First, confirmation of these results and replication within a larger scale (RCT) is necessary. Specifically, further investigation into differential response patterns, with increased n to provide power to generalizations, would be beneficial to clarify conclusions. Another suggestion is that clear documentation of multisensory intervention procedures should be included not just within the research process but also in the publication of results. Specific details of sensory input used, alone or in combination, provides valuable information. With incomplete knowledge of sensory input for a therapeutic technique, we run the risk as a profession of overlooking potential impacts on intervention outcomes.

Finally, further research should be considered for its ability to bridge our knowledge into practice. Many studies are confined to homogenous participants for theoretical reasons. However, quality information is also needed for the heterogeneous population that exists in today's schools. We need to support our professionals in use of effective and efficient teaching techniques with their "real" children, who demonstrate a variety of comorbid diagnoses and compounding factors.

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Article Tables

Table 1: *Summary of Participant Characteristics*

	Participant 2	Participant 3	Participant 4	Participant 5
Age at Start of Study	5;5	4;7	6;9	4;8
Gender	Male	Male	Female	Male
Race/Ethnicity	Caucasian	African-American	Asian	Latino
Global Language Severity	Mild	Severe	Within Normal Limits	Within Normal Limits
Receptive Language Severity	Within Normal Limits	Moderate	Within Normal Limits	Within Normal Limits
Expressive Language Severity	Moderate	Severe	Mild	Mild
Grammar Severity	Mild	Severe	Severe	Moderate
Co-morbid Disorders and Severity	Moderate Articulation Delay (Childhood Apraxia of Speech)	Severe Articulation Delay; Moderate Attention Deficit Disorder	Severe Articulation Delay (Repaired Cleft Palate); Moderate Attention Deficit Disorder	Severe Articulation Delay
Behavioral Regulation Severity	Above Criterion	Below Criterion	Above Criterion	Above Criterion
Metacognition Severity	Above Criterion	Below Criterion	Above Criterion	Below Criterion
Global Executive Function Severity	Above Criterion	Below Criterion	Above Criterion	Below Criterion
Observed Activity Level	Appropriate	High	High	Moderate

Table 2: *Participant Language Characteristics*

Participant	Total Language Score	Receptive Language Score	Expressive Language Score	Total Grammar Score (Criterion)	Third Person Singular (Criterion)	Past Tense (Criterion)	Be (Criterion)	Do (Criterion)
P2	**82**	102	**76**	**59.8** (66)	**56** (89)	**12** (73)	89 (79)	82 (56)
P3	**69**	**75**	**59**	**10.5** (59)	**0** (76)	**0** (73)	**42** (93)	**0** (46)
P4	93	100	**83**	**28** (81)	**0** (91)	**35** (87)	**33** (90)	**45** (76)
P5	88	101	**83**	**25** (59)	**10** (76)	**0** (73)	**33** (93)	58 (46)

Note. Language Scores are based on a mean of 100, standard deviation of 15. Specific grammar scores reflect performance on the Test of Early Grammatical Impairment (Rice & Wexler, 2001), with scores below expectations for the participant's age marked in **bold font**. Criteria for each participant's age are shown in parantheses.

Table 3. *Participant Executive Function Characteristics*

BRIEF Subtest and Composite Scores	Participant 2	Participant 3	Participant 4	Participant 5
Inhibit	69	**62**	80	76
Shift	70	**50**	**64**	**40**
Emotional Control	71	**38**	**63**	71
Behavioral Regulation Index	73	**50**	72	67
Initiate	**55**	**42**	**59**	**46**
Working Memory	68	**60**	81	**53**
Plan/Organize	72	**41**	72	**<37**
Organization of Materials	69	**56**	70	**53**
Monitor	66	**51**	**62**	**47**
Metacognition Index	68	**50**	73	**43**
Global Executive Composite	72	**50**	75	**53**

Note: Subtest and composite T-scores reported from the Behavior Rating Inventory of Executive Function (Gioia, Isquith, Guy, & Kenworthy, 2015). Scores below expectations for the participant's age are marked with **bold font**.

Table 4. *Average Production Accuracy in Acquisition Activities Across Phases and Participants*

		Motor Production Percentage Mean (Standard Deviation)	Visual Production Percentage Mean (Standard Deviation)	Control Production Percentage Mean (Standard Deviation)
P2	Baseline	63 (18.0)	43 (13.4)	51 (8.4)
	Intervention	85 (11.8)	76 (20.0)	40 (12.5)
	Maintenance	94 (5.5)	88 (8.4)	52 (13.0)
P3	Baseline	8 (8.7)	1 (2.2)	17 (14.0)
	Intervention	50 (22.6)	53 (32.4)	42 (18.8)
	Maintenance	42 (18.8)	15 (27.7)	54 (29.7)
P4	Baseline	21 (11.5)	18 (18.8)	77 (26.3)
	Intervention	73 (10.7)	69 (8.2)	4 (10.6)
	Maintenance	33 (22.9)	68 (28.4)	0 (0)
P5	Baseline	10 (8.2)	8 (11.7)	22 (16.1)
	Intervention	55 (19.6)	57 (27.2)	5 (9.5)
	Maintenance	48 (11.8)	55 (7.7)	6 (5.2)

Table 5. *Average Production Accuracy in Retention Probes Across Phases and Participants*

		Motor Production Mean (Standard Deviation)	Visual Production Mean (Standard Deviation)	Control Production Mean (Standard Deviation)
P2	Baseline	40 (15.8)	44 (15.2)	28 (8.4)
	Intervention	72 (25.3)	60 (18.5)	-
	Maintenance	76 (26.1)	52 (26.8)	-
	Generalization	94 (8.9)	66 (8.9)	36 (8.9)
P3	Baseline	0 (0)	0 (0)	6 (8.9)
	Intervention	10 (18.5)	0 (0)	-
	Maintenance	32 (26.8)	0 (0)	-
	Generalization	0 (0)	0 (0)	8 (8.4)
P4	Baseline	45 (25.9)	35 (37.3)	76 (13.7)
	Intervention	40 (18.5)	30 (32.1)	-
	Maintenance	44 (30.0)	36 (21.9)	-
	Generalization	44 (11.4)	18 (20.5)	58 (13.0)
P5	Baseline	7 (8.2)	2 (4.1)	22 (9.8)
	Intervention	13 (10.4)	23 (22.5)	-
	Maintenance	40 (0)	64 (16.7)	-
	Generalization	42 (13.0)	48 (8.4)	12 (8.4)

Table 6. *Functional Use of Target Structures in Natural Language*

Participant	Sample Time	Motor Targets		Visual Targets		Control Targets	
		Percent Correct	Number of Attempts	Percent Correct	Number of Attempts	Percent Correct	Number of Attempts
P2	Initial	100%	2	71%	7	100%	2
	Final	100%	3	100%	5	100%	12
P3	Initial	0%	4	0%	7	70%	10
	Final	50%	2	60%	5	53%	17
P4	Initial	100%	1	24%	17	100%	1
	Final	100%	2	32%	22	100%	1
P5	Initial	0%[a]	2[a]	0%[b]	0	0%[b]	0
	Final	50%[a]	2[a]	100%	2	50%	2

[a] P5's motor target was *do* question inversion. No attempts were made at this target within either of his natural language samples. The data reported is on general inverted questions. [b] No attempts were made at this target, so accuracy level is reported as 0% by default.

Table 7. *Generalized Language Improvement from Language Sample Analysis*

Participant (SUGAR Norm Group)	Time	TNW	*z-*score	MLU$_S$	*z-*score	WPS	*z-*score	CPS	*z-*score
P2	Initial	276	-0.387	6.28	-0.28	5.80	-1.26	**1.05**	**-1.8**
(5;0-5;11)	Final	279	-0.339	6.28	-0.28	5.85	-1.22	**1.23**	**-0.5**
P3	Initial	172	-1.774	3.68	-1.89	**4.30**	**-2.13**	0.98	-2.1
(4;6-4;11)	Final	223	-0.926	4.96	-0.92	**6.97**	**-0.02**	1.21	0.0
P4 (6;0-6;11)*	Initial	238	-1.376	4.98	-1.64	*6.03*	*-1.42*	1.08	-2.0
(7;0-7;11)*	Final	267	-1.798	5.98	-1.67	*5.45*	*-2.82*	1.08	-2.2
P5	Initial	**143**	**-2.257**	**2.96**	**-2.44**	4.53	-1.95	1.00	-1.9
(4;6-4;11)	Final	**322**	**0.72**	**6.62**	**0.33**	6.44	-0.44	1.12	-0.8

Note. Positive changes of more than a standard deviation are designated in **bold font**. Negative changes of more than a standard deviation are designated in *italic font*.

Table 8. *Implementation Fidelity by Participant and Phase*

Participant	Baseline	Intervention	Maintenance	Participant Total
2	85%	92%	85%	88%
3	95%	100%	90%	96%
4	80%	74%	65%	73%
5	90%	93%	65%	84%
Grand Total	**88%**	**90%**	**76%**	**85%**

Article Figures

Past Tense -ed

Flat hand moves from
palm-up waist level to
palm-down over
shoulder

Plural -s

S-hand moves from chest
level front of body to the
right at arm length

Pronoun *he*

E-hand moves from
forehead level forward
and down to arm length
in the direction of the
referent or referent's
picture
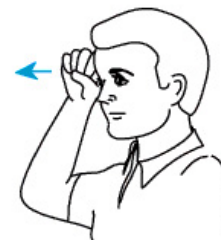
Illustrations provided by Signing Exact English web dictionary, https://www.signingexactenglish.com/see.asp

Figure 1. Examples of Motor Techniques
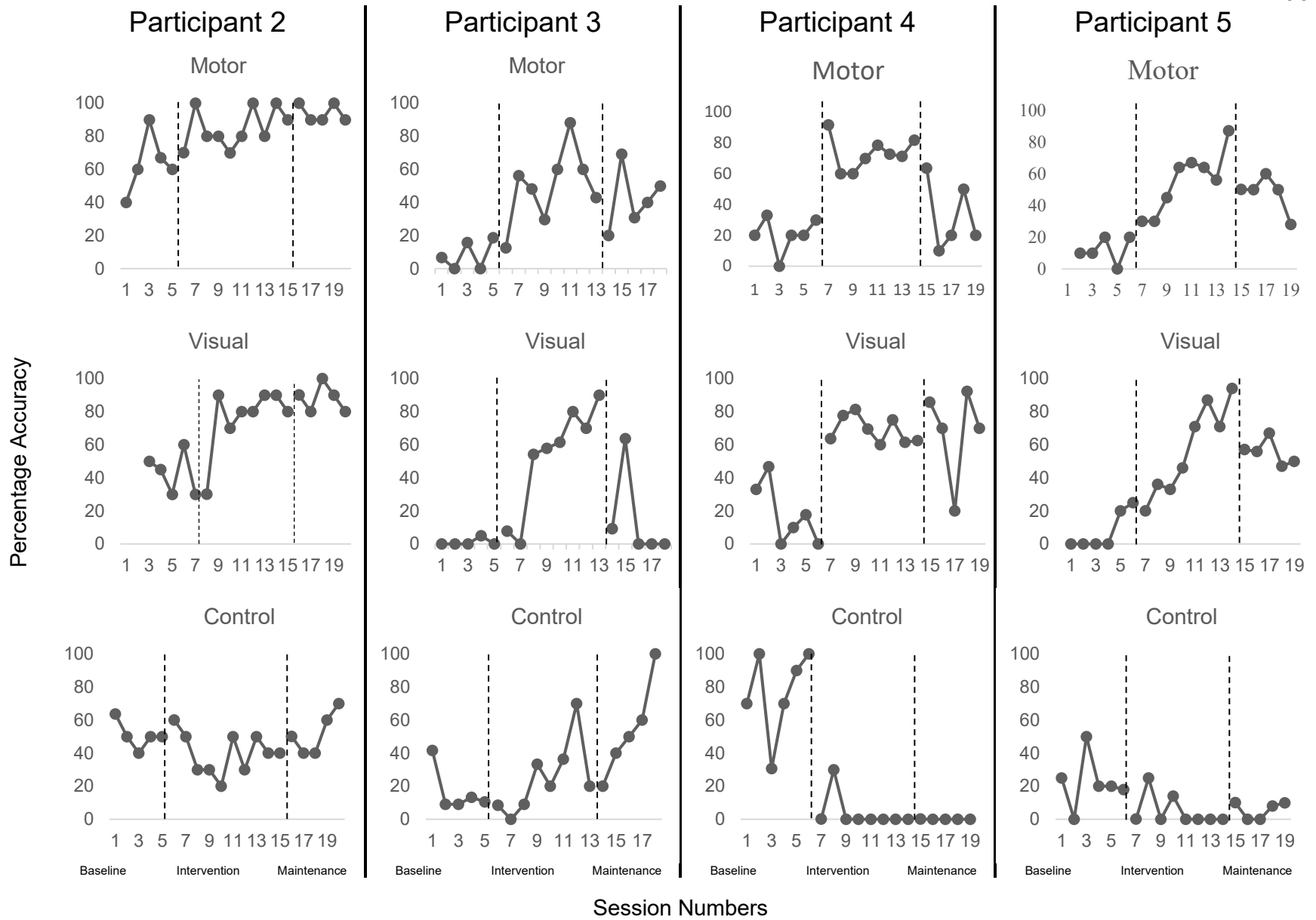
Figure 2. Acquisition Data Across Participants, Targets, and Phases
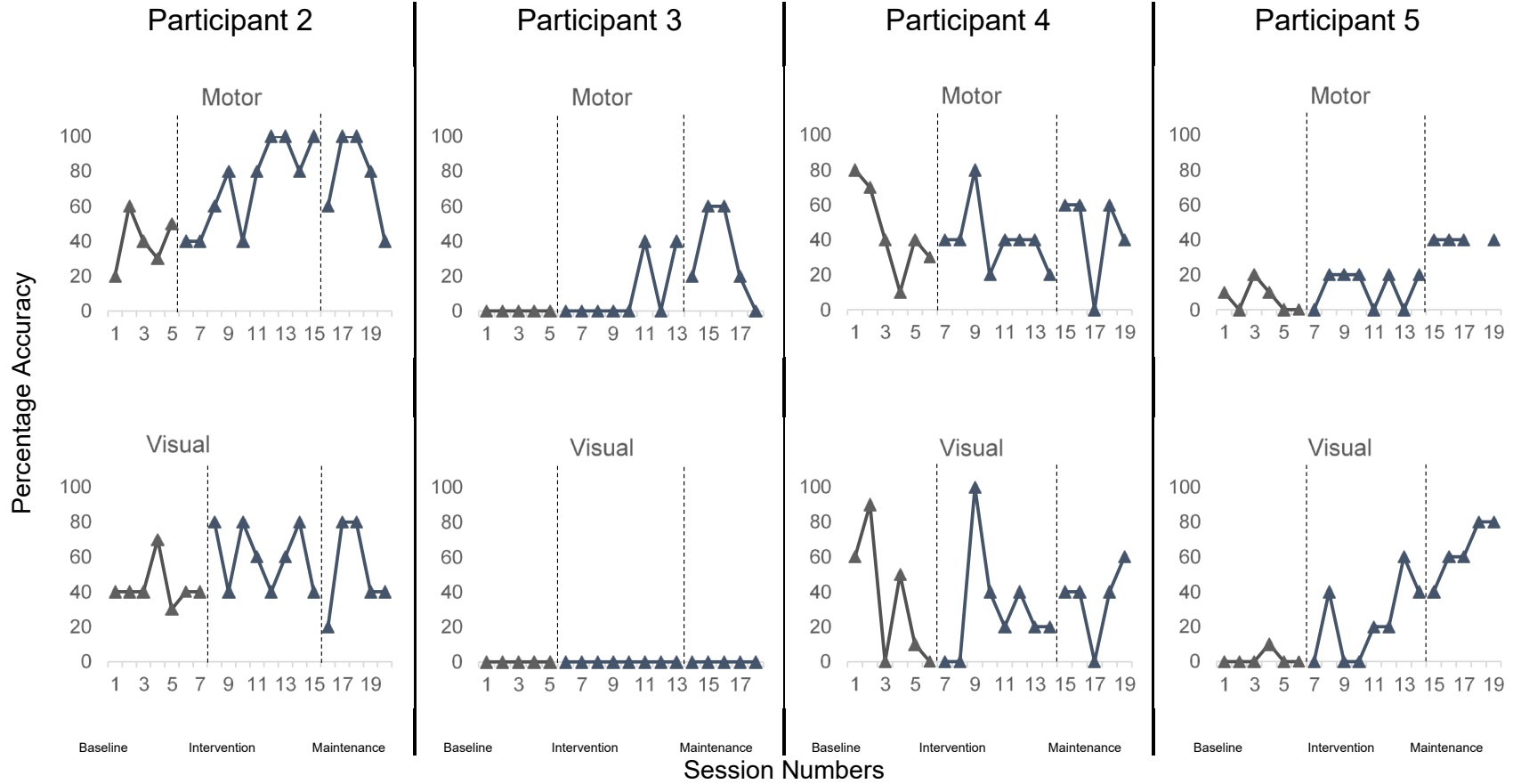
Figure 3. Retention Data Across Participants, Targets, and Phases
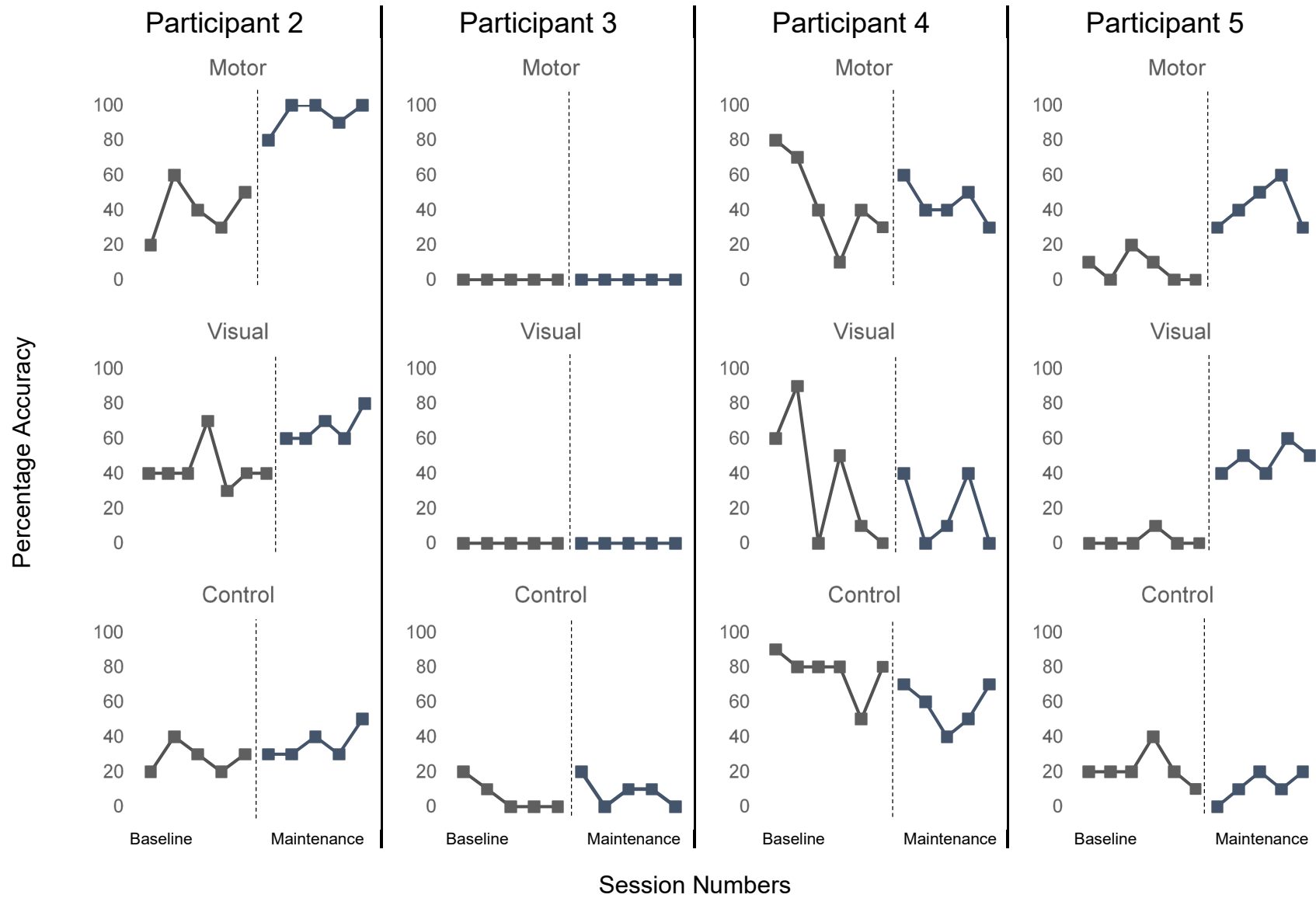
Figure 4. Generalization Data Across Participants, Targets, and Phases

Literature Review

There are approximately 89,000 certified speech-language pathologists serving almost 4,000,000 children with communication disorders in schools in the United States (American Speech-Language-Hearing Association [ASHA], 2019). Many of these children have a communication disability specific to the understanding and use of language (Bishop et al., 2017). This chapter will review terminology and prevalence of language impairment and the centrality of grammar concerns within that diagnosis. These topics will be followed by discussion of the relevance of single- and multi-sensory instruction for children with language impairment. Then, a systematic review of existing sensory techniques within recent interventions for grammar impairment will be provided. Finally, the chapter will end with remaining gaps in the empirical literature.

Language Impairment Definitions

In 2015, there were 1,332,000 children with primary speech or language impairments served in kindergarten through high school in public schools in the United States of America (United States Department of Education [USDOE], 2018). Language impairments often occur without corresponding difficulty articulating sounds in children ages two to seven years (Law et al., 2000). A recent population estimate of school-age children with language impairment yields a prevalence rate of just under ten percent (Norbury et al., 2016). Some of these children will face difficulties in language skills that do not resolve completely (Law et al., 2000). In fact, up to one-third of children identified with language impairment in kindergarten meet the criteria for dyslexia by third grade (Catts, Adlof, Hogan, & Weismer, 2005), an occurrence that may have contributed to the additional 2,278,000 children identified with specific learning disabilities in the 2014-15 school year (USDOE, 2018). Early language impairments are significantly

associated with low reading and math achievement, increased likelihood of mental health and behavior disorders, and limited employment in adulthood (Committee on the Evaluation of the Supplemental Security Income (SSI) Disability Program for Children with Speech Disorders and Language Disorders et al., 2016).

Language impairments are categorized as either language delays (i.e., typical sequence of skill development at atypically slow rate) or language disorders (i.e., atypical patterns of skill development resulting in an overall insufficiency for language function). Within the United States, the term language impairment recognizes those children with receptive or expressive difficulty in communication due to either delay or disorder. It should be noted that language impairment is a heterogeneous label, including oral and written language delays and disorders, as well as more narrowly defined impairments, such as specific language impairment, developmental language delay, and even dyslexia (Berninger & Wolf, 2016; Bishop et al., 2016). Thus, any review of literature which focuses on language impairment will encounter multiple terms that define difficulties within a multilevel language spectrum. The consensus term Developmental Language Disorder (DLD; Bishop et al., 2017) is used throughout the rest of this document to refer to language impairment where no direct cause can be ascertained.

The impact of DLD can include limited achievement in literacy, resulting in academic underachievement, difficulties in peer relationships, and frequent bullying (Bishop et al., 2019; National Institute on Deafness and Other Communication Disorders, 2011). Children with DLD continue to manifest negative educational and post-academic outcomes. They have a significantly higher drop-out rate than age-matched typically developing peers (Hadley, 2004). Young adults with DLD may also be significantly less independent in adult tasks of self-care, traveling, social interaction, and financial responsibilities (Conti-Ramsden & Durkin, 2008).

DLD is present in up to 88% of young adults who are unemployed (Elliott, 2011) and 52% of

adolescents who are incarcerated (Anderson et al., 2016). Even those young adults with DLD

who report wellbeing similar to their typically developing peers may be more vulnerable to

negative impacts of health, employment, and relationship challenges (Conti-Ramsden et al.,

2016).

These children often demonstrate comorbid diagnoses, including dyslexia, attention

deficit hyperactivity disorder, intellectual disabilities, emotional and behavioral disorders, autism

spectrum disorder, developmental coordination disorder, and dysgraphia (Biotteau, Chaix, &

Albaret, 2015; Cantiani, Lorusso, Perego, Molteni, & Guasti, 2015; Catts et al., 2005;

Pinborough-Zimmerman et al., 2007; Richards, Abbott, & Berninger, 2015; Tükel, Björelius,

Henningsson, McAllister, & Eliasson, 2015). Multiple diagnoses often lead to multiple areas of

need both within communication learning and in other developmental skills. School personnel

teams, legally required to provide an appropriate education to each student with DLD, must

prioritize the individual's areas of need for intervention ("Every student succeeds act," 2015;

Idea improvement act, 1997).

Effective treatments for DLD exist (Cirrin & Gillam, 2008; Law, Garrett, & Nye, 2004;

Law, Plunkett, & Stringer, 2012), and are routinely provided by SLPs (ASHA, 2016; ASHA,

2018). Within education settings, each student's needs must be prioritized within the finite

resources of the schools. The length of the school day imposes constraints on the time available

for instruction, while the financial status of the school district imposes constraints on educators

and related service personnel available for instruction. Children with DLD have specific

instructional needs, such as increased repetitions for learning, as well as additional sensory

supports (Birsh, 2011; Eisenberg, Nippold, & Hoffman, 2014; Kamhi et al., 2014; Reid,

Lienemann, & Hagaman, 2013). Most children with these needs access instructional time within a regular education classroom, which often does not have the resources and personnel needed. Thus, whatever time can be provided to the student with DLD through direct instruction with appropriately trained interventionists must be used not only effectively to learn, but efficiently to learn as much as possible.

Grammar within Language Impairments

One of the most commonly prioritized instructional targets for children with DLD is grammar and syntax development (Kamhi et al., 2014). This priority reflects the viability of delayed grammar development, such as use of verb tense markers and sentence repetition skills, as diagnostic features for DLD (Pawłowska, 2014). Differences in grammar development can be tracked in children with DLD across time (Leonard et al., 2017). Remediation of grammar tends to be difficult, and often fails to generalize (Hsu & Bishop, 2014). Also, difficulties in grammar tend to persist in verbal discourse, and appear in other domains, such as written language skills (Mackie et al., 2013). Because grammar and syntax moderate the meaning of verbal utterances, appropriate grammar is necessary in order to effectively and meaningfully communicate. Children with DLD frequently require specific grammar intervention to do so.

Types of Grammar Intervention. At a basic level, grammar interventions can be categorized as implicit interventions and explicit interventions. Implicit interventions focus on presenting multiple receptive and expressive opportunities to engage children' statistical learning abilities, and often use models and recasts within naturalistic activities. Implicit interventions have been found to be effective for grammar development with preschool and school-age children (Cleave, Becker, Curran, Owen Van Horne, & Fey, 2015; Smith-Lock, Leitao, Lambert, & Nickels, 2013). Explicit interventions use children' metacognitive abilities to mediate their

language understanding and use by directly teaching the rules of grammar. Explicit interventions also have research-based support (Ebbels, 2007; Smith-Lock et al., 2013). Systematic review of existing literature for grammar interventions indicates that explicit approaches may be better for older children, and implicit approaches for younger children (Ebbels, 2014); however, the relationship between children's age, severity of delay, and response to different interventions is currently unknown. Children with receptive language difficulties appear least likely to show progress, but in general, one-to-one intervention by an SLP has been shown to be effective (Ebbels, 2014).

Grammar Interventions in Clinical Use. A recent survey of practicing SLPs investigated how grammar intervention approaches are applied clinically (Finestack & Satterlund, 2018). Clinicians reported directly targeting grammatical forms with an average of 61% of their preschool-age children, and an average of 48% of elementary-age children. Finestack and Satterlund (2018) found that nearly all practicing SLPs reported using implicit techniques, such as models (100% for early education providers; 99% for elementary age providers), recasts (95% for early education providers; 92% for elementary age providers), natural play (100% for early education providers; 83% for elementary age providers), and book reading (96% for early education providers; 92% for elementary age providers). Many SLPs also reported the use of explicit techniques, such as direct presentation (95% for early education providers; 96% for elementary age providers), drill activities (83% for early education providers, 91% for elementary age providers), worksheets (41% for early education providers, 70% for elementary age providers), and academic coursework (28% for early education providers, 73% for elementary age providers). Data from Finestack and Satterlund (2018) confirm that many

SLP practices align with current evidence-based practices, and indicated that implicit and explicit techniques are frequently used in combination.

Effectiveness of Grammar Interventions. Ebbels' (2014) systematic review of grammar interventions for effectiveness provided evidence of effectiveness for varied intervention techniques. For example, the largest quantity of evidence (19 primary studies) was found for intervention targeting expressive grammatical structures, such as verb argument, question formation, and finite morpheme use. The strongest of these primary studies demonstrated positive results, maintenance, and generalization for explicit instruction of verb argument structure. Implicit strategies, such as grammar facilitation with imitation also demonstrated positive results. When intervention was focused on understanding grammatical structures, only six primary studies were identified. Three of the highest quality of these studies used explicit techniques and demonstrated significant, but not universal, positive child outcomes. Ebbels (2014) concluded that both implicit and explicit grammar approaches are generally effective, with potentially differential results based on child characteristics and/or targeted grammatical structures. Cases of individual difference were noted where a minority of participants responded to only one intervention technique, such as recasting, while another group responded only to a different intervention technique. Also noted was the potential impact of developmental readiness for young children with DLD, including indications that children may be more amenable to implicit treatment techniques if the target grammatical structure is emergent in their language and that children with comorbid phonology disorders respond differently to different intervention session structure (Ebbels, 2014).

These grammar intervention procedures, within both theoretically-relevant research and clinical current practice, explained broad teaching actions (Ebbels, 2014; Finestack & Satterlund,

2018), but fail to address the neurobiological basis of how individuals learn. This necessitates an understanding of children's experiences as they learn and how different sensory input techniques may contribute to successful learning. The next section reviews different sensory modalities that contribute to learning.

Sensory Techniques in Language Interventions

The importance of using hands-on, multi-sensory materials to help children learn was outlined by Maria Montessori over 100 years ago (Culclasure et al., 2019). The provision of visual, auditory, tactile, and kinesthetic sensory inputs are common among interventions for children with learning disabilities (Farrell & Sherman, 2011) and the potential for motor treatment techniques to benefit language recall and production has been demonstrated with both adults with acquired aphasia (Ferguson et al., 2012) and preschool children (Bedard et al., 2017). Evidence-based practice (EBP) in intervention for development of oral language include a range of different sensory techniques (Farrell et al., 2004). For example, techniques such as drawing attention to the mouth of the teacher to support identification of specific sounds and identifying affixes within text to support understanding of meaning of the word are specifically visual inputs.

The discussion of sensory techniques that follows provides operational definitions that will be used throughout the rest of this chapter. *Visual techniques* depend only upon seeing the provided support, while *auditory-verbal techniques* rely on the naturally paired ability to hear input that is spoken orally. The static sensation of touch, or tactile input, and the feeling of body motion, or kinesthetic input, are also frequently paired stimuli. For example, it is difficult to functionally separate tactile and kinesthetic components within interventions in which young

children touch and/or move the materials. For consistency, the term *motor techniques* will be used when tactile and/or kinesthetic sensations are evoked.

Auditory-Verbal Techniques. Ebbels' (2014) review of grammar intervention techniques identified common use of verbal productions directed to the child's auditory sensory system. In fact, textbook descriptions of language facilitation techniques use adult verbal models and conversational verbalization procedures to define the procedures (Fey, 1986; McCauley, Fey, & Gillam, 2017). Both Ebbels (2014) and Finestack and Satterlund (2018) record verbal direct instruction within explicit techniques, while Ebbels (2014) often notes its use in combination with visual or motor techniques.

Determining the primary sensory modality from published articles is challenging at best. For example, when an intervention procedure designated the shared use of stories (Buschmann et al., 2009), this procedure could indicate a motor input, but the description lacked specific confirmation that interventionists had allowed their participants to handle the books. Simultaneous input through the visual modality of sequenced color pictures, inherent to the use of books (Petersen, 2011; Swanson, Fey, Mills, & Hood, 2005; WWC, 2010), must also be acknowledged. These examples illustrate the principle of naturally paired stimuli, which create a congruent input situation for targeted structures. Shams and Seitz (2008) detail the importance of harmonious multisensory learning by demonstrating how it expands the potential neuronal changes beyond that of multiple independent or unassociated sensory modalities. The researchers further note that multisensory congruencies are experientially driven. Thus, an arbitrary multisensory pairing, such as a previously unknown icon with a familiar auditory verbalization (a procedure within the narrative intervention of Petersen, Gillam, Spencer, & Gillam, 2010), may become equally as effective as a naturally simultaneous occurrence, such as

pictures and page-turning of books, when the learning period is extended across time (Shams & Seitz, 2008).   The compatibility of multisensory paired inputs, whether natural or arbitrary, may explain findings that longer periods of training or higher dosages of intervention have a differential impact on outcomes (Law et al., 2004; Petersen, 2011; Tosh, Arnott, & Scarinci, 2017). Naturally paired stimuli occur repeatedly throughout EBP interventions for language (Springle, in preparation).

Visual Techniques. Shape Coding[TM] is an example of a visual intervention, developed and described by Ebbels (2007). This intervention for systematic and explicit instruction of grammar was specifically designed for children with language learning disabilities, such as DLD. There are several features of Shape Coding that reflect the needs of these learners. First, Shape Coding recognizes that students with DLD can benefit from practice accessing, coordinating, and organizing language for expression (Reid et al., 2013). It integrates grammatical learning tasks across both oral and written modalities and can be taught in comprehension and expression. This aspect clearly aligns with research-based recommendations for teaching reading and writing to students with learning disabilities (Berninger & Wolf, 2016).

Students with DLD often benefit from explicit instruction. Shape Coding provides explicit instruction, in child-friendly terms, for many aspects of grammar, including parts of speech, noun-verb agreement, passive and active sentences, verb tense, embedded structures, and conjunctions (Ebbels, 2005). Focus within this intervention is placed upon being able to identify and build appropriately grammatical sentences through learned knowledge, and not intuition. Children are taught to associate shapes with sentence structure, colors with grammar function, lines with noun and verb number, and arrows with tense. They are taught the combinations of these structures as they exist in English, both receptively and expressively. Thus, Shape Coding

helps to develop an effective grammar strategy, reducing the likelihood of learned helplessness. Sentences are modeled and guided in construction, aligning this intervention with yet another research-based guideline for teaching students with DLD (Berninger & Wolf, 2016).

A variety of experimental methodologies accepted as potential evidence by What Works Clearinghouse (What Works Clearinghouse, 2017) have been utilized in examination of the effectiveness of Shape Coding. The primary studies that make up the evidence base supporting Shape Coding is summarized in Table 3. Three studies used a randomized controlled trial approach (Ebbels, 2005; Ebbels, Marić, Murphy, & Turner, 2014), three studies reported results from a quasi-experimental design (Ebbels & van Der Lely, 2001; Kulkarni et al., 2014). The remainder used a variety of single subject research designs, including a multiple baseline study and an alternating treatment study (Bolderson, Dosanjh, Milligan, Pring, & Chiat, 2011; Ebbels, 2007; Engman, 2017).

Insert Table 1

Other features of quality evidence are present within the existing Shape Coding studies. Attrition rates for all reported studies were 0% (Bolderson et al., 2011; Ebbels, 2005, 2007; Ebbels et al., 2014; Ebbels & van Der Lely, 2001; Ebbels, van Der Lely, & Dockrell, 2007; Kulkarni et al., 2014), indicating that the experimental samples demonstrate a low bias threat using optimistic and cautious assumptions (What Works Clearinghouse, 2017). Baseline equivalence is established in both the RCTs and quasi-experimental designs, and outcome measures are not too tightly bound to the intervention design (Ebbels, 2005, 2007; Ebbels et al., 2014; Ebbels & van Der Lely, 2001; Kulkarni et al., 2014). Several included single subjects research design studies demonstrated appropriate 3-point baseline measures and clear change with the introduction of intervention (Bolderson et al., 2011; Engman, 2017).

All studies reported positive effects from the Shape Coding intervention (Ebbels, 2005, 2007; Ebbels et al., 2014; Ebbels & van Der Lely, 2001; Ebbels et al., 2007; Engman, 2017; Kulkarni et al., 2014), with an effect size up to a moderate 0.38 (Ebbels, 2005; Ebbels et al., 2007). Most studies reported that the students made real-world, clinically significant improvement as well (Bolderson et al., 2011; Ebbels, 2005; Ebbels et al., 2014; Ebbels & van Der Lely, 2001; Ebbels et al., 2007; Engman, 2017), with only a few intervention non-responders noted (Ebbels, 2007; Kulkarni et al., 2014).

Motor Techniques. Research from recent studies suggests that interventions using deliberate physical movements can also help improve academic outcomes for children with disabilities (Donnelly et al., 2009; Erwin, Fedewa, Beighle, & Ahn, 2012; Sullivan, Kuzel, Vaandering, & Chen, 2017). Average effect sizes are moderate and positive within the academic areas of reading, writing, oral language, and mathematics (Springle & Roitsch, 2018). Research indicates that teaching motions to preschool children has a synergistic impact on their word learning beyond that expected from simply adding another sensory input (Callcott, Hammond, & Hill, 2015). Motor, as movement, is ideally suited to intervention use. Gestures are clearly established as complementary communication means, co-developing with language (Capone & McGregor, 2004; Iverson, 2010; Iverson & Braddock, 2011). They require no additional materials or space to use within intervention. Gestures represent both the tactile sensation of touch and the kinesthetic sensation of motion. Formal symbolic motor, such as the word signs from an established sign language, can also been used to teach language. Recent research demonstrated that children with DLD increase word learning when signs are paired with the verbal productions (van Berkel-van Hoof, Hermans, Knoors, & Verhoeven, 2019).

Undifferentiated Modalities. Although auditory-verbal techniques define many grammar intervention techniques, interventions for young children with language impairment often fail to differentiate the sensory modalities utilized within their procedures. In many cases, the auditory-verbal techniques are explicitly included in intervention protocols (e.g., Alpert & Kaiser, 1992), while visual or motor techniques are only incidentally noted. For example, "participating in a shared book reading" (Crain-Thoreson & Dale, 1999, p. 31) may give each reader a different idea of the visual and motor components to the intervention. It is not clear which individual holds the book, turns the pages, or even if the use of gestures to point to shared referents or augment spoken communication is permitted, encouraged, or required. Lack of detailed sensory descriptions impede further analysis of effectiveness. However, a recent pilot study provided a foundation for comparing the use of visual and motor modalities as viable supports for children who are learning grammatic structures (Springle & Hester, in press).

Comparing Sensory Techniques. Data collected during the pilot study with two children with oral language delay documented a clear and immediate response to the implementation of the intervention for both child participants. Despite the potential ceiling effects with Child 2, the data documented the effects of paired auditory-verbal and visual intervention techniques and paired auditory-verbal and motor techniques. Within this pilot study, the child with a high activity level and challenges in sustained attention responded to paired auditory-verbal and motor intervention techniques more quickly than paired auditory-verbal and visual techniques. The child with typical activity level and attention abilities responded equally well to both paired techniques. Though the pilot study had limitations, e.g. only two participants, potential data skew due different individual characteristics, and implementation differences across clinicians, it is the only study that allows examination of outcomes for differential impact

of the sensory modalities within an intervention. The preliminary suggestion is that a child's

level of executive function may moderate the response to different sensory modalities of

intervention techniques.

Further information on specific single and paired sensory techniques within current

grammar interventions has the potential to guide best practice and result in more efficient and

effective outcomes for children with language impairments. The following literature review

gathers this information from recent peer-reviewed primary studies with grammar as an outcome

variable.

Method of the Literature Review

Search Procedures

For this review, a search for empirically supported practices for grammar in preschool

and school age children was conducted from a selection of education, allied health, and medical

databases, including Education Source, PsycNet, Language and Linguistics Behavior Abstracts,

and Web of Science. Search terms included *grammar* and *intervention*, as the focus of this

review. Specific search terms for each database are detailed in Figure 1. The article search was

limited by publication date to those from January 2014 to the July 2019. These dates were set to

capture only the most current best practices, following the grammar intervention review of

Ebbels (2014), which included articles in press through February 2014. This search yielded a

total of 459 peer-reviewed articles.

The researcher reviewed the titles and abstracts of all articles. There were three primary

inclusion criteria: (a) the article described a primary intervention study; (b) the population

included children between birth and 15 years old; and (c) a grammar skill was measured in

outcome. From review of titles and abstracts, 46 articles were identified. Duplicate articles were

then eliminated, leaving 23 articles to be read in their entirety. Articles were excluded if the participants demonstrated no language impairment or an impairment associated with sensory deficits, such as hearing impairment ($n = 3$). The final count for inclusion was 20 recent primary studies detailing grammatical intervention results.   The data necessary to describe grammar interventions and outcomes, as well as define sensory input modes was extracted from each article.

Figure 1. Literature Search Summary

Data Extraction

Population summary statistics were noted for age range and identified disabilities of participants. The grammatical targets, experimental aspects, and results of the included studies were noted. To provide information on service delivery models and treatment dosage, these components of each intervention were captured as well. The therapy techniques reported within each study were assigned to one of three primary modalities: visual, auditory-verbal, or motor. Assignment was based on the child's method of receiving that information. On multiple occasions, information on visual or motor techniques were not described within the primary studies, making it impossible to extract information on visual or motor techniques.

Insert Table 2

Results

Characteristics of grammar interventions.   Significantly, all studies reported positive outcomes, in terms of clinical or statistical improvement for the majority of participants. Of those studies using a single subject research design (Bredin-Oja & Fey, 2014; Calder et al., 2018; Curran & Owen Van Horne, 2019; Feehan, Francis, Bernhardt, & Colozzo, 2015; Kulkarni et al., 2014; Shahmahmood Toktam et al., 2018; Smith-Lock, 2014), 24 of the 34 participants

demonstrated improvement in targeted skills, four demonstrated a mix of improvement and stable skill development, and the remaining six students demonstrated no progress in skill development. Thus, grammar interventions were effective for 82% of participants within single subject research design studies. These studies included participants identified with expressive language delay, DLD or SLI, and language disorder associated with autism spectrum disorder. Grammatical targets included single finite markers, such as past tense *-ed,* and more complex syntactic structures, such as production of causal adverbials.

Most grammar interventions were provided individually by speech-language pathologists. Only four interventions provided services in groups (Eidsvåg Sunniva et al., 2019; Phillips, 2014; Smith-Lock, 2014; Smith-Lock, Leitão, Prior, & Nickels, 2015). Eidsvåg Sunniva et al. (2019) directly compared results between individual and group-of-two treatments and reported clinical improvement for 70% of participants with minimal practical differences between delivery models. Most interventions targeted students between the ages of 4;0 and 10;0, with only one study including children as young as 2;6 (Bredin-Oja & Fey, 2014) and five others extending beyond age 10;0 (Balthazar & Scott, 2018; Hsu & Bishop, 2014; Ramirez-Santana et al., 2018; To Carol et al., 2015; Zwitserlood et al., 2015).

Successful aspects of the interventions included greater effectiveness from combined explicit and implicit intervention methods (Calder et al., 2018; Finestack, 2018), increased generalization of the target grammatical structure from high-variability practice conditions (Owen Van Horne et al., 2018; Owen Van Horne et al., 2017; Plante et al., 2014), and equal efficacy in both frequent short and less frequent longer scheduled sessions (Balthazar & Scott, 2018; Meyers-Denman Christina & Plante, 2016).

Visual techniques. Visual input techniques were unable to be extracted from five of the studies (Feehan et al., 2015; Finestack, 2018; Owen Van Horne et al., 2018; Smith-Lock, 2014; Smith-Lock et al., 2015). Techniques described within other articles included written stimuli or text for reference (Balthazar & Scott, 2018; Calder et al., 2018; Curran & Owen Van Horne, 2019; Kulkarni et al., 2014; Phillips, 2014; Ramirez-Santana et al., 2018; Shahmahmood Toktam et al., 2018; To Carol et al., 2015; Zwitserlood et al., 2015), written or drawn production practice (Balthazar & Scott, 2018; Curran & Owen Van Horne, 2019; Hsu & Bishop, 2014; Owen Van Horne et al., 2017; Phillips, 2014; Ramirez-Santana et al., 2018), stimuli selection derived from the child's visual attention or specific visual cues to attend (Bredin-Oja & Fey, 2014; Eidsvåg Sunniva et al., 2019; Meyers-Denman Christina & Plante, 2016), the systematic use of colors, shapes, and lines (Calder et al., 2018; Kulkarni et al., 2014; Zwitserlood et al., 2015), and picture representations of the semantic context of targets (Owen Van Horne et al., 2017; Plante et al., 2014; Shahmahmood Toktam et al., 2018; To Carol et al., 2015). The frequent use of picture and text stimuli and the use of self-generated visual materials suggest that visual techniques may be a valuable component of effective grammar interventions. Table 3 presents the different types of sensory techniques used across reviewed studies.

<div align="center">Insert Table 3</div>

Auditory-verbal techniques. All reviewed studies reported extensive use of auditory-verbal teaching and support techniques. Included frequently were oral instruction, oral target models, elicitations, and recasts, as well as systems of oral prompts. Oral stimuli were provided by both computer (Balthazar & Scott, 2018; Finestack, 2018; Hsu & Bishop, 2014) and live clinicians (Bredin-Oja & Fey, 2014; Calder et al., 2018; Curran & Owen Van Horne, 2019; Kulkarni et al., 2014; Owen Van Horne et al., 2018; Owen Van Horne et al., 2017; Phillips, 2014;

Plante et al., 2014; Ramirez-Santana et al., 2018; Shahmahmood Toktam et al., 2018; To Carol et al., 2015; Zwitserlood et al., 2015). Auditory but non-verbal cues, such as a finger-snap or the sounding of a bell, were used infrequently to establish attention (Eidsvåg Sunniva et al., 2019; Meyers-Denman Christina & Plante, 2016). The use of auditory-verbal techniques within grammar intervention appears universal.

Motor techniques. Teaching and support techniques involving motor aspects of touch and movement could not be extracted from 9 of 20 articles (Bredin-Oja & Fey, 2014; Feehan et al., 2015; Finestack, 2018; Hsu & Bishop, 2014; Owen Van Horne et al., 2018; Phillips, 2014; Shahmahmood Toktam et al., 2018; Smith-Lock, 2014; Smith-Lock et al., 2015). Techniques identified within other studies included writing or drawing for production practice (Balthazar & Scott, 2018; Curran & Owen Van Horne, 2019; Kulkarni et al., 2014; Owen Van Horne et al., 2017; Ramirez-Santana et al., 2018; To Carol et al., 2015), motoric actions such as moving or pointing to visual cues (Calder et al., 2018; Zwitserlood et al., 2015), tactile cues to establish attention (Eidsvåg Sunniva et al., 2019; Meyers-Denman Christina & Plante, 2016), and re-enactment of targets in context (Owen Van Horne et al., 2017; Plante et al., 2014; Ramirez-Santana et al., 2018).

Discussion

Most of the studies within this review recorded some form of oral instruction, an explicit instruction technique of which frequent use was reported by clinicians within the recent survey of Finestack and Satterlund (2018). The implicit instruction techniques of verbal models and recasts were also reported frequently in both research and practice. While grammar interventions clearly described multiple auditory-verbal teaching and support techniques, the descriptions of additional sensory components were more limited. This result agrees with findings within the

larger scope of evidence-based practices in language interventions generally (Springle, in preparation). While visual techniques were specified in three-quarters of included articles, descriptions of techniques that involved motor and touch were present in just over half of the included articles.

Another common feature of existing literature and the current review is the inclusion of naturally paired stimuli. Naturally paired stimuli are the result of combined multisensory inputs. Within this review, several interventions used writing production practice or drawings which create a paired visual and motor stimuli (Balthazar & Scott, 2018; Curran & Owen Van Horne, 2019; Kulkarni et al., 2014; Owen Van Horne et al., 2017; Ramirez-Santana et al., 2018; To Carol et al., 2015). When the child creates the drawing or writes the text, there is a simultaneous access to visual support and the motor and touch of guiding the writing tool across paper. Similarly, several interventions reported the deliberate attainment of child attention before providing practice items or opportunities. Two of these three studies reported use of visual, auditory-verbal, and tactile cues to gain attention (Eidsvåg Sunniva et al., 2019; Meyers-Denman Christina & Plante, 2016). In some studies, explicit mention of such visual techniques as written text and drawing and auditory-verbal techniques as oral stimuli and oral cueing were present without clear reference to any motor techniques (Bredin-Oja & Fey, 2014; Hsu & Bishop, 2014; Phillips, 2014; Shahmahmood Toktam et al., 2018). In others, only the auditory-verbal techniques were explained (Feehan et al., 2015; Finestack, 2018; Owen Van Horne et al., 2018; Smith-Lock, 2014; Smith-Lock et al., 2015). Yet, in at least one of these cases (Smith-Lock et al., 2015), the study described materials, such as modeling clay and books, which imply some inherent paired sensory input of the described auditory-verbal techniques with these visual and tactile materials. It seems possible that various sensory modalities used within these

interventions were not regarded as an essential factor, and thus, not reported clearly. However, research clearly supports the value and effectiveness of multi-sensory learning (Birsh, 2011; Farrell & Sherman, 2011; Reid et al., 2013; Shams & Seitz, 2008).

Limitations of the Current Review

The purpose of this review was to identify specific features of current effective grammar interventions, including the sensory techniques used. Although the articles were initially sourced from several complementary databases, it is possible that existing interventions were inadvertently overlooked within the search. Identification of intervention features was limited by the descriptions available within published articles. Another limitation of this review is the intended populations and disability characteristics of the literature supporting of each EBP. Although the intent was to include only those children between preschool and second grade in development, and with language impairments only, the nature of the existing literature was heterogenous. The applicability of findings and conclusions drawn from them may be impacted by unintended inclusion of study results with differing requirements for participants. Finally, this review required the documentation of intervention procedures by the primary modality of provision. This undertaking was difficult and required the review and analysis of very diverse interventions. It was the researcher's intention to record only those modality techniques that could be clearly determined from the high-quality primary studies including the target population. The result of this decision may have impacted conclusions drawn.

Implications for Further Study

The first sections of this chapter establish the necessity of meeting the language needs of children with DLD, establish the relevance of grammar development to this population, and review existing knowledge of effective intervention components. Although effective

interventions exist, the literature has generally reported undifferentiated sensory teaching techniques. Because they are less often documented than auditory-verbal techniques, it may be assumed that visual and motor techniques are less essential to effective interventions; however, this may not be true. Existing studies of interventions to improve grammar development in young children have not analyzed the multiple sensory components (e.g., visual, auditory-verbal, or motor techniques). Thus, there is a need for further investigation of the impact of the use of specific sensory modalities within language intervention. This is particularly true in view of existing empirical gaps aligning individual child characteristics, such as level of executive function development, with specific characteristics of different intervention techniques.

Methodology

This chapter outlines a single case design study comparing treatment effectiveness and efficiency of two different intervention techniques to increase the use of grammatical structures by children with DLD. Both interventions used auditory-verbal models examined in existing empirical studies and clinical practice but differed in the paired sensory input provided. Specifically, verbal strategies were paired naturally with either a systematic visual support or a systematic motor support. The research questions are presented first, followed by a description of study features to assure the research adheres to the standards and procedures of the What Works Clearinghouse Standards and Procedures Handbooks (2017). The timeline of the study procedures is delineated next. Participant selection, study setting, and materials are described, and then study measures are provided. Descriptions and rationale for the independent and dependent variables are reviewed. The intended procedures to assess the reliability and validity of the gathered data and intervention fidelity are detailed, and finally data analysis plans are outlined.

Setting

All study sessions were conducted in a small room located in a speech and language clinic on the campus of a University on the East Coast of the United States. Each room was approximately 10' X 10' and typical of those used for individual interventions. Each room was carpeted and furnished with a child-sized table and chairs. In order to reduce child distraction, a tall cupboard in one corner was used to store session materials until they were needed.

Research Questions

1. Is there a functional relation between language interventions that pair verbal support with a) systematic visual or b) systematic motor with the use of grammatical structures by children with developmental language delay (DLD)?

2. Does the rate at which children with DLD learn grammatical structures differ between language interventions that pair verbal support with a) systematic visual or b) systematic motor?

3. Does the sensory modality pair used within language interventions impact the generalization and/or maintenance of use of grammatical structures by children with DLD?

4. Are novice clinicians able to implement both interventions with fidelity?

5. Did the clinicians using language interventions that pair verbal support with a) systematic visual or b) systematic motor find these intervention strategies useful and effective when teaching grammatical structures to children with DLD?

6. Did the caregivers of children receiving language interventions that pair verbal support with a) systematic visual or b) systematic motor find the intervention strategies useful and effective for teaching grammatical structures to their children with DLD?

Research Design

This study used a single-subject adapted alternating treatment research design. This design was chosen for its applicability to special education populations and ability to compare the efficiency of treatments for nonreversible behaviors (Ledford & Gast, 2018; Rakap, 2015). The adapted alternating treatment design allows for the implementation of two different

interventions addressing functionally equivalent, non-reversible behaviors for comparison with lowered risk of multi-treatment interference (Sindelar et al., 1985). The study was designed to meet the standards for single subject research within What Works Clearinghouse recommendations (WWC; 2017) . Specifically, the single subject research design allows for demonstration of causality. Within this alternating treatment design, five or more measurement points in each condition of the study were planned, meeting the requirement that treatment effects be demonstrated at least three times. Consistent with an adapted alternating treatment design, the design included the counter-balancing of relevant non-experimental variables, such as time of session and order of implementation (Sindelar et al., 1985). The type of intervention provided first within the session was randomized within each participant, using random.org's coin flipper program (Haarh, 2019). No more than three sessions using the same implementation order occurred, to minimize order-of-presentation effects. Another important factor to consider when using the adapted alternating treatment design is equivalent and functionally independent sets of target behaviors. The equivalence and independence of potential target grammatical structures can be determined from existing knowledge of those structures appropriate to children's developmental level which are often resistant to change in children with DLD. A logical analysis of targets was conducted to prevent induction of intervention effects. Further independence of targets was established through sampling data on a control structure, again of equivalent level of difficulty. The control structure consisted of a grammatical structure produced incorrectly by the child which was not targeted for intervention. The assessment of control structure production also allowed detection of maturational change, a potential threat to internal validity (Ledford & Gast, 2018). Consideration of baseline performance verified equivalence in target performance levels prior to the start of intervention.

Sequence of the Study

A sequence of the study procedures was presented in Figure 2 and detailed below.

Insert Figure 2.

Identification. For initial screening, each child completed a language sample and the TEGI screening subtests, scheduled in one 45-minute session. To fulfill inclusion criteria, existing language standard scores were documented.

Evaluation. If recent language standard scores were unavailable or more than three years old, a 1-1 ½ hour evaluation session was scheduled, and the CELF-5 or CELF-P:2 was administered. Although the TILLS was also available for administration, none of the clients were of the appropriate age range. The TEGI Be/Do subtest was also administered, to complete the grammar assessment tasks, although it was allowed to take place in a second evaluation session if the child participant had reached the limits of their cooperation. When documentation of an existing language impairment and significant difficulty with at least three grammatical structures was assured, parent participants were asked to complete the BRIEF. Details on all of these assessment tools may be found in the Measures section of this chapter.

Baseline. Baseline phase consisted of a minimum of five twice-weekly 30- to 45-minute sessions scheduled at parent and child participant, graduate student clinician, and researcher availability. The total number of baseline sessions ultimately depended on the level and trend of the data. In each baseline phase session, child participants completed a 30-item probe task. Ten items for each of three targeted grammar rules were elicited without verbal, visual, or motor supports. The structures included the two targeted by intervention techniques, as well as a control structure. Selection of target grammatical structures is described within the Independent

Variables section, while probe assessments are fully described below, within the Dependent

Variables section.

The second section of each baseline phase session consisted of two 15-minute activities.

Each activity was designed to provide obligatory contexts for production of one target

grammatical structure. No verbal, visual, or motor supports were provided within these

activities; however, production data were recorded to track initial production within a naturalistic

task. The order of these activities was counter-balanced, as described within the Research

Design section.

Intervention. In the treatment phase, eight 30- to 45-minute intervention sessions were

scheduled twice weekly over the course of four to five weeks. At the beginning of the

intervention session, a probe assessment of each participant's retention of the grammatical target

was completed. Each probe assessed five treated contexts for each intervention target. The term

treated context identifies an actual child production connecting the target grammatical structures

with a specific vocabulary term, such as the word *cats* (targeting the plural marker).

Following the retention probe, two intervention activities were completed. The first task

of each session was an intervention activity, targeting only one of the chosen grammatical

structures and using either visual or motor intervention strategies, randomly determined. Efforts

were made to include activities that were of interest to the participants, based on parent and/or

child indications of preferred activities. Children were actively engaged in the activities. The

second task of each intervention session was another intervention activity, targeting a second

grammatical target using the remaining intervention strategy. Procedures were parallel; the only

systematic difference was the treatment strategy. Details of the interventions and the

implementation protocol are provided below within the Independent Variables section of this chapter.

Maintenance. Maintenance was assessed in 45- to 60-minute sessions, two held on the established twice-weekly schedule immediately following the intervention phase and one session each at two, four, and six weeks post-intervention. These sessions parallelled the child's intervention experience thus far. A brief statement encouraging participants to use their special color and motor words was provided at the beginning of each session, i.e. "Remember, you can use your special words so I understand you." No further practice, details, or reminders were provided. A 10-item probe of treated contexts from throughout the intervention sessions assessed retention of learning at the beginning of each maintenance assessment. The two alternating activity blocks were duplicated without feedback or cues to correct production. Although alternating treatment design demonstrates experimental control through the first set of phase change across participants (Horner et al., 2005), five data points were recorded in maintenance to further describe the treatment outcome and ensure WWC standards were met (WWC, 2017).

Following these activities, the initial probes, which contain vocabulary contexts that had not been included in the intervention phase, were re-administered to serve as a generalization measure. To further assess generalization, a language sample was collected and the productivity of control, motor intervention, and visual intervention structures was determined. Productivity is reported as a percentage created by the number of correct grammatical structures spontaneously produced divided by the number of grammatically-mandatory contexts included within the sample.

Participants

Participants in the study included child participants, their parents or caregivers, and graduate student clinicians in the speech-language pathology program. The term *parent participants* is used to refer to parents or caregivers of participating children. They were asked to provide information about their child and their perceptions of the intervention and its outcome. *Graduate student clinicians* were recruited from the speech-language pathology program to serve as student clinicians in the research study. These students had less than two years of clinical training and agreed to commit the time and effort necessary for training and implementing the components of the research study. The *child participants* were early primary-aged children (four to seven years of age) who were diagnosed with DLD.

Recruitment. Child and parent participants were recruited through several channels. First, local therapy business owners and/or managers were contacted with information about the study. Copies of an information flyer were provided for disbursement to their speech-language pathologists and educators. Those providers were asked to give the flyer, with the researcher's contact information, to the parents or caregivers of children who might meet inclusion criteria. Second, this general procedure was followed to contact head speech-language pathologists and intervention coordinators within local public and private schools. These individuals chose whether to allow their speech-language pathologists to provide the flyer to parents or caregivers of clients who might meet inclusion criteria, in accordance with the organizational policies. Finally, the flyer was posted online in the Homeschooling in Hampton Roads Facebook group and local school division, PeachJar websites, and physically in local libraries for residents who wished for their children with DLD to participate.

Informed consent documents for both child and parent participants were presented to parents or caregivers following their initial contact with the researcher. These documents were reviewed in person at a mutually agreed upon time before the child participant completed any screening, assessment, or intervention sessions.

Graduate student clinicians were self-identified volunteers, recruited through brief presentations by the researcher. This research study was discussed, with instructor permission, in specific classes in the Communication Disorders master's program, e.g. CSD 651, CSD 656, or CSD 659. Follow-up emails were sent to all eligible master's level clinicians to identify a time for a face-to-face meeting to discuss the study in more detail and present the Consent to Participate form. Involvement or lack of involvement in the study did not impact the graduate student clinicians clinical or academic program success in any way. Participants were free to withdraw at any point, as participation was completely voluntary. Study sessions were scheduled at a time convenient to parent and child participants, graduate student clinicians, and the researcher.

Inclusion. Referrals were accepted for children whose parents or SLPs reported concern with understanding and expression of ideas in language. A confirmed language disorder and delay in grammar skills was required for participation in the study. Following completion of Consent to Participate forms, the Test of Early Grammatical Impairment (TEGI; Rice & Wexler, 2001) was used to identify a delay in grammatical skills and determine possible target grammatical structures for intervention in recommended children. Please see Measures for details on the administration and scoring of the TEGI. Target grammatical structures were confirmed with a language sample analysis, from a 50-utterance conversational or narrative sample. The specific procedures for this language sample analysis are described within the

Dependent Variables section of this chapter. For each child who demonstrated at least three

potentially equivalent grammatical errors, presence of DLD was confirmed. Confirmation

through existing standard scores, including report of at least -1.0 standard deviations below

norms on a composite score from a published comprehensive language measure, was accepted.

If evaluation had not taken place, or was more than three years old, the child was re-evaluated by

the researcher or a graduate student clinician under direct supervision of the doctoral student

researcher. Details of this evaluation are available within the Measures section of this Chapter.

     Exclusion. Children with sensory impairments, such as hearing loss, and/or physical

impairments, such as moderate to severe hypotonia, were excluded from this study, as they could

not fully engage with the paired sensory stimuli. Children with unintelligible speech or a mean

length of utterance (MLU$_S$) less than 2.0 morphemes were also excluded, as these conditions

resulted in functional inability to measure any grammatical structure use.

     Response to Recruitment. Twenty-five inquiries were received from child participant

recruitment procedures. Informed consent documents for both child and parent were presented

to potential parent participants following their initial contact with the study researcher. These

documents were reviewed in person before the child participant completed any screening,

assessment, or intervention sessions. Sixteen potential participants were screened for sufficient

length of utterance, multiple potential grammar targets, and the ability to respond to TEGI

protocols. Six potential participants were excluded due to expressive language at the single-

word level or below. Five potential participants declined further involvement in the study for

various reasons, including transportation and time commitment. Five participants were

identified. All five sets of parent participants provided consent for both the child participants

and themselves. Demographic characteristics of child participants are located in Table 4. Table

5 provides information on child participant language skills pre-intervention. Information on

participant executive function skills pre-intervention is available in Table 6. Participant 1, a six-

year, six-month-old Caucasian male native English speaker, was withdrawn from the study in

baseline phase as he did not maintain a stable baseline with any potential grammatical target.

Participant 2. Participant 2 (P2) was a Caucasian five-year, five-month-old male with

previous diagnoses of childhood apraxia of speech and expressive language delay. He spoke

English as his only language. His referring speech therapist indicated continuing difficulty with

personal pronouns and copula production, despite functional motor planning ability, as well as

continuing difficulty with verb tense markers. His initial language sample revealed a MLU_S

within age expectations. Uncontractible copula and third person singular -*s* were nonproductive.

Difficulties with irregular plurals and possessive pronouns were noted within limited

spontaneous production opportunities. On the Test of Early Grammar Impairment (TEGI), P2

earned a total score of 59.5, below the expected criterion of 66. Areas of greatest challenge

included third person singular -*s* and past tense. Stimulability indicated that P2 was able to

produce /s/, /z/, /d/, and /t/. Grammatical targets chosen included copula *be* verbs, possessive

pronouns, and regular past tense. Following equivalency probes, copula *be* targets were

withdrawn due to higher comparative spontaneous production. Third person singular -*s* was

substituted, and assigned to the visual intervention condition for the duration of the study.

Possessive pronouns were assigned to the motor intervention condition and regular past tense

was the control structure.

Participant 3. Participant 3 (P3) was a four-year, seven-month-old African-American

male with existing diagnoses of articulation disorder, mixed expressive-receptive language

disorder, and attention deficit hyperactivity disorder. P3's family spoke English with a standard

dialect and some community exposure to African-American dialect. His initial language sample revealed a MLU$_S$ below age expectations. Past tense verbs, copula *be*, auxiliary *be*, third person singular -*s*, regular plurals, possessive – *'s*, and pronoun case were nonproductive. On the Test of Early Grammar Impairment (TEGI), P3 earned a total score of 10.5, below the expected criterion of 59, with all areas of assessment below criteria. Articulation assessment confirmed severe articulation delay, with inconsistent active phonological processes. Stimulability indicated that P3 was able to produce /s/, /z/, /d/, and /t/. Grammatical targets chosen included copula *be* verbs (specifically *was* and *were*), regular past tense, and *do* question inversion. *Do* question inversion was assigned to the visual intervention condition for the duration of the study. Regular past tense was assigned to the motor intervention condition and copula *be* was the control structure.

Participant 4. Participant 4 (P4) was a six-year, nine-month-old Asian female with existing diagnoses of articulation disorder secondary to cleft palate, attention deficit hyperactivity disorder, and expressive language delay. P4 had no exposure to her birth language past the age of approximately four months and was considered a native English speaker. Her initial language sample revealed a MLU$_S$ below age expectations. Copula *be*, plurals, auxiliary *be*, and third person singular -*s* were nonproductive. On the Test of Early Grammar Impairment (TEGI), P4 earned a total score of 28, below the expected criterion of 81, with all areas below criteria. Stimulability indicated that P2 was able to produce /s/, /z/, /d/, and /t/ with some distortion on fricative sounds. Grammatical targets chosen included copula *be* verbs, regular past tense, and *do* question inversion. Copula *be* statements were assigned to the visual intervention condition for the duration of the study. Regular past tense was assigned to the motor intervention condition and *do* question inversion was the control structure.

Participant 5. Participant 5 (P5) was a four-year, eight-month-old Latino male with no previous diagnoses of communication disorders. He was a native English-speaker. His mother reported concern with both articulation and language expression. His initial language sample revealed a MLU$_S$ below age expectations. Past tense verbs, copula *be*, auxiliary *be*, third person singular -*s*, regular plurals, possessive – *'s*, and question inversion were nonproductive. On the Test of Early Grammar Impairment (TEGI), P5 earned a total score of 25, below the expected criterion of 59, with all areas of assessment below criteria. Articulation assessment confirmed severe articulation delay, with inconsistent active phonological processes. Stimulability indicated that P5 was able to produce /z/ in the word /ɪz/ (*was*) but did not reliably produce /s/, /z/, /d/, and /t/ in other contexts. Grammatical targets chosen included copula *be* verbs (specifically *was* and *were*), regular past tense, and *do* question inversion. Following equivalency probes, copula *be* targets were withdrawn due to higher comparative spontaneous production. Relative clause production was substituted and assigned to motor intervention condition for the duration of the study. *Do* question inversion was assigned to the visual intervention condition and regular past tense was the control structure.

Five graduate student clinicians were self-identified volunteers, recruited through the previously outlined procedures. Two of the graduate clinicians were within their third semester of on-campus practicum experience when the study began; they each had previous experience with no more than two child clients. One graduate student clinician was in her first semester of on-campus practicum experience and two graduate student clinicians had not yet begun clinical practicum. All three of these graduate student clinicians began this study as their first clinical experience. The graduate student clinician in her first semester of practicum, who was assigned to Participant 1, withdrew from the study at the same time as her child participant.

Materials

Materials for use in this intervention included those typically used in language therapy sessions with young children. Materials that support shared reading, interactive play, and craft activities (e.g. children's books, play kitchen sets and tool benches, dolls and race cars, and craft materials) were selected from the shared clinical inventory. Materials for therapy activities were selected to match each child participant's developmental level and interests and allowed for the natural occurrence of the individual's targeted grammatical structures. Therefore, each session's materials were unique to each child and his or her intervention targets. Specific supplementary materials for the visual intervention corresponded to the Shape Coding^{TM} intervention, as described by Ebbels (2007). These materials were provided to the graduate student clinicians to maintain the consistency of the established intervention across participants, as noted in the Sequence of the Study section. No supplementary materials were necessary to support the motor intervention. Data collection forms for all study tasks were provided to the graduate student clinicians by the researcher. These forms included the Implementation Fidelity Checklists for Baseline, Intervention, and Maintenance. They are located in Appendix A.

Measures

Test of Early Grammatical Impairment (TEGI; Rice & Wexler, 2001). This test provides an in-depth assessment of grammatical skills by structure and had not been clinically administered to any participant. The TEGI screening portion consists of two subtests, a regular third person assessment and past tense assessment. The TEGI screening test was designed to determine the need for intervention services, and the results of the screening portion were used to identify potential participants. Scores that fell below the provided screening criterion scores, based on the six-month age interval of the child, allowed child participant inclusion. Criterion

scores with their related sensitivity and specificity information are available in Table *7*. All child

participants also finished the TEGI instrument through completion of the remaining Be/Do

subtest. Careful analysis of the TEGI subtests was used to establish individual patterns of

production for regular third person singular -*s*, regular and irregular past tense, production of

singular and plural copula and auxiliary *be* verbs in questions and statements, and production of

singular and plural *do* verbs in questions. This information was used to determine potential

intervention targets.

Test of Integrated Language and Literacy Skills (TILLS; Nelson, Plante, Helm-

Estabrooks, & Hotz, 2016). The TILLS was administered to verify language disorder for child

participants above the age of 6;0 without existing language standard scores or for those with

scores more than three years old. The TILLS was selected as a formal assessment instrument of

comprehensive language abilities with high sensitivity and specificity.

Clinical Evaluation of Language Fundamentals – Preschool (CELF-P:2; Semel, Wiig,

& Secord, 2004). Potential child participants between 4;0 and 6;0 without existing language

standard scores or with scores more than three years old were tested using the CELF-P:2. This

test was chosen as a comprehensive language instrument with better psychometric properties

than other options for children in this age group (Denman et al., 2017).

Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, &

Kenworthy, 2015). The BRIEF parent scale was completed to determine each participant's level

of executive function development. Because the results of a pilot study suggested that children

with difficulty in executive function may respond differentially to language interventions that

pair verbal support with a) systematic visual or b) systematic motor, this measurement

documented individual child participant characteristics for comparison to intervention outcomes.

Independent Variables

  Visual and Verbal Intervention.

  The paired visual and verbal independent variable used the conventions of Shape Coding, including the use of specific colors to represent different parts of speech, arrows and underlines to represent tense and number, and specific shapes to represent sentence structure. Relevant shape, color, and underline conventions are illustrated in Appendix B. In this study, shapes were outlined and cut from neutral-colored cardstock, then laminated for durability. Dry erase markers were used to add text for child participants who read. Line drawings or photo cards could be placed within appropriate shapes to represent correct use of specific vocabulary at the discretion of individual clinicians. Clinicians presented or referenced the visual supports for each target production within intervention activities. Children were permitted to use colored writing tools to create their own shapes, arrows, and underlines as appropriate during craft activities.

  Motor and Verbal Intervention. The paired motor and verbal independent variable used a systematic representation of grammatical structures through easily performed movements, or gestures. This motor component included both the sensation of motion (kinesthesia) and the touch where hand shapes met. This intervention was developed by the researcher, predicated on the idea that young children move and that motor patterns are associated with language development (Lavelli & Majorano, 2016), and with consideration of the existing literature. The intervention was designed to parallel the Shape Coding's systematic visual representations of grammatical structures through equivalent representational movements. Refer to Figure 3 for examples of motor techniques.

<div align="center">Insert Figure 3</div>

Specific gestures for this study were developed from an established grammatically-representative motor code, i.e. Signing Exact English (Gustason & Zawolkow, 1993). In the proposed study, clinicians completed the movements associated with each target production within intervention activities. For example, the clinician would say "The dinosaur walk<u>ed</u> away" while making the sign for past tense as the regular past tense morpheme *-ed* was produced. Children were encouraged to supplement verbal target productions with these motor movements. Maximal range of motion was modelled and elicited in each movement.

Intervention Protocol. Each chosen grammatical structure was assigned to a single intervention technique for the duration of the study. Within the first intervention session, the graduate student clinicians introduced each intervention technique with a brief verbal script and demonstration, then guided each participant through one to three practice items, providing specific feedback to the child participant. This explicit instruction was repeated briefly at the beginning of each relevant activity within each subsequent intervention session. At the beginning of each activity, child participants were informed which intervention technique was to be used during that activity. Clinicians selected activities that allowed at least ten opportunities to elicit each child's grammatical structure(s).

Clinicians utilized implicit teaching procedures during each intervention activity to prevent child participants from disengaging from the treatment session. These procedures included repeated modelling of the target grammatical structure in the chosen intervention technique. They provided indirect verbal cues, recasts, and direct mands to elicit at least ten natural productions of the grammatical structure. Prompt feedback for both correct (e.g. I like how you used your *-s* ending) and incorrect productions (e.g. Remember to use your good *-s*

ending) was provided. The type of feedback was determined in real time by the clinician as the most appropriate to the child and natural to the situation.

Dependent Variables

As the dependent variable, grammatical targets were carefully chosen to be of equivalent difficulty for the individual children, to meet the assumption of functional equivalency required by an adapted alternating treatment design (Ledford & Gast, 2018; Sindelar et al., 1985). In agreement with the findings of Eidsvåg Sunniva and colleagues (2019) that children with DLD do not generalize to separate targets, the results of a pilot study suggested that cross-categorical targets, such as verb tense makers (e.g. past tense *-ed*) and noun number markers (e.g. plural *-s*) do not affect the learning of the other grammatical targets (Springle & Hester, in press). Thus, careful selection of targets helped to minimize potential multi-treatment interference.

Probes. Both retention and generalization of grammatical targets were measured by specific probes. Retention refers specifically to the ability to use a target grammatical structure with words that were used within an intervention session, or a *trained semantic context*. Generalization refers to the ability to use the trained grammatical structure with words that have not been specifically targeted, or an *untrained semantic context*. Assessment of generalization was completed through pre- and post-intervention probes. These consisted of 30 items; ten items from untrained semantic contexts for each of three grammatical structures were presented. The structures included those assigned to visual intervention and motor intervention, as well as a control structure. One model item and one practice item were presented before each probe, allowing clinicians to ensure their child participants understood the task. Probe items consisted of a picture illustrating a targeted grammatical structure within a sentence, and included a sentence starter, such as "In this picture, we see . . . ." Child responses were transcribed and

scored for accuracy of the targeted grammatical structure. Pre-intervention probes items were presented in random order at the beginning of each baseline session. Post-intervention probe items were presented in random order at the beginning of each maintenance session.

Repeated probes to measure each participant's retention of their grammatical target were completed at the beginning of each intervention session. Each probe assessed five treated semantic contexts for each intervention condition. The probe format parallelled the pre- and post-intervention probes previously described, including one trial item, and a sentence starter, such as "In this picture, we see . . . ." A five-item probe of treated contexts from throughout the intervention sessions was administered in each maintenance phase session to assess retention. Although a 10-item probe had been planned for maintenance phase, this proved to be too long for the attention abilities of the child participants.

Acquisition data. Production counts from within the intervention activities were collected to track each child's acquisition of their target behavior. The data included the number of mandatory opportunities for target production and the number of times each child produced the target correctly. Both independent correct productions and productions supported by a model, recast, or indirect verbal cue, e.g. "Can you say that again?" were counted as correct responses, although they were coded differently within raw data. These data allowed comparison of the number of productions attempted and the number produced correctly by each client to assess differences in total number of production attempts between clients. These data also allowed computation of the percentage of correct productions within each intervention session.

Functional use. Functional use of the grammatical structures was elicited through a conversational or play-based language sample. This 50-utterance sample was elicited using process questions, such as *how* and *why,* and prompts such as *tell me more*. If these procedures

failed to elicit 50 utterances, a picture book would have been provided and the child encouraged

to talk about the pictures in the story. Production ratio during the sample was derived by

recording the number of correct productions divided by the number of mandatory opportunities.

This measurement differed from the acquisition production data described above as no

productions were prompted or directly elicited. All samples were recorded using the Video,

Audio, Learning Tool (Intelligent Video Solutions, 2015) and/or a handheld voice recorder, and

transcribed using Sampling Utterances and Grammatical Analysis Revised conventions (Pavelko

& Owens Jr, 2017). The doctoral student independently duplicated 20% of transcriptions and

compared for reliability of coding. Any differences in the language sample transcript utterances

were resolved by consensus of the graduate clinician, research assistant, and researcher. Specific

measures of grammar target productivity and general measures of language development,

including Total Number of Words (TNW), Mean Length of Utterance (MLU_S), Words Per

Sentence (WPS), and Clauses Per Sentence (CPS) were documented on both initial and final

language samples for each child participant. The general measures were converted to z-scores

using norms from the SUGAR procedure to allow comparison of changes.

Implementation fidelity. To assess the ability of novice clinicians to implement visual

and motor interventions for grammar improvement, data were collected for each clinician-client

pair during each phase of the study. Implementation fidelity of procedures were assessed in 40%

(2/5) of randomly-selected baseline probes, 37% (3/8) of intervention activities, 43% (3/7) of

intervention retention probes, 40% (2/5) of maintenance retention probes, and 40% (2/5) of

generalization probes. Each graduate student committed to observe and code their peers' fidelity

in all phases of the study. Sessions were assigned randomly, and fidelity was measured on a

point-by-point checklist of required components for each phase and task (See Appendix A).

Additional fidelity ratings were provided by the researcher and trained research assistants. Research assistants received one hour of guided practice coding implementation fidelity, and point-by-point agreement greater than 90% was achieved on a practice coding session before study coding began. Although, implementation fidelity was monitored on a weekly basis through the study no feedback or additional training was provided unless implementation fidelity fell below 50% in any measured session.

      Social validity. Social validity address issues relevant to effectiveness of an intervention by assessing importance and acceptability (Ledford & Gast, 2018). There are three recognized elements of social validity (Foster & Mash, 1999) within the existing literature. Goal importance, the first element, was assured by comparing each participant's performance to the normative values to determine treatment justification. An element of subjective evaluation was inherent to the study, as potential participants who demonstrated no concern with functional use of grammar did not contact the researcher. The two remaining elements of social validity, intervention acceptability and outcome importance, were assessed through subjective rating by graduate student clinicians and parent participants. Subjective evaluation is appropriate when information is provided by caregivers of individuals with disabilities, and reflects the qualitative societal judgments of intervention effectiveness (Foster & Mash, 1999).

      The potential benefit and clinical utility of each intervention technique were assessed by graduate student clinicians and parent participants. Each graduate student completed a questionnaire following their final maintenance session about their experiences learning and providing the treatment. They were asked to assess the value of each intervention modality pair and indicate if they have a preference. Each parent participant also completed a short questionnaire, designed to elicit their thoughts and experiences about the appropriateness and

appeal of visual and motor interventions, as well as identify their preference between the two. Responses to six questions were measured on a 5-item Likert scale, from *Strongly Agree* to *Strongly Disagree*. One question asked the parent participant to choose their preferred intervention technique and four open-ended questions gathered related information. The social validity questionnaires are available for review in Appendix C.

Reliability. The reliability of study data were assessed by independent observers during baseline probes, intervention activities, maintenance or retention probes, the generalization measures, and functional use samples. The first observer was the graduate student participant, who collected data on her assigned participant during real time within the study sessions. The researcher or a trained research assistant served as second observer, collecting data from video recordings of randomly-selected sessions for each participant. Research assistants received one hour of guided practice coding data, and point-by-point agreement greater than 90% was achieved on a practice coding session before study coding begins. To meet WWC guidelines, inter-observer agreement was assessed on at least 20% of each phase with each participant, specifically 40% (2/5) of baseline probes, 37% (6/16) of intervention activities, 43% (3/7) of intervention retention probes, 40% (2/5) of maintenance retention probes, and 40% (2/5) of generalization probes. In accordance with best practice (Ledford & Gast, 2018; WWC, 2017), inter-assessor agreement was assessed statistically for consistency with intraclass correlations derived from the percentage of grammatical targets correct in acquisition as well as retention data. The interclass correlation (model 3, form 1) with absolute agreement assesses variability in both sequence and magnitude of single measurement scores across observers within a single study (Trevethan, 2017). The target ICC for reasonable clinical measurement was greater than 0.90, identified as a conservative value by Trevethan (2017), although ICC values > 0.75 could

be deemed acceptable. If an ICC value below 0.85 was calculated, individual data session results were compared, relevant research assistants were retrained, and divergent sessions were recoded.

Data Analysis

Data analysis was intended to be comprehensive, providing clear descriptions of data through both visual analysis and statistical modelling. Visual analysis served as the primary evaluation tool for the results of both probe data and acquisition data, and included level, trend, and phase change comparisons from each study phase (Horner et al., 2005; Ledford & Gast, 2018). Data level stability was measured with a 20% envelope criterion based on median value (Ledford & Gast, 2018). To aid in interpretation, Tau-U effect estimates were generated from nonparametric statistical analysis of the data completed in accordance with Parker et al. (2011), using the Tau-U calculator application (Vannest et al., 2016).   Tau-U was appropriate as a comparison statistic due to its compatibility with visual analysis and its ability to account for level change across phase and positive baseline trends. Effect sizes were predetermined such that a score lower than or equal to 65 represented no or mixed effect, a score between 66-92 represented a clear effect, and a score greater than 93 represented a strong effect (Rakap, 2015).

Results

Results are discussed by individual participant. Data from within session acquisition activities is provided first. Then, information on retention of learning across sessions is presented, followed by generalization measures from similar probes. Finally, generalization of specific target features into functional use and generalized language improvement are offered.

Participant 1

P1 began baseline sessions with a motor structure target of copula *be*, a visual structure target of regular past tense, and a control structure of subject pronoun-verb agreement. Baseline in all three structures was highly variable. An alternate motor target was measured for three additional baseline sessions to establish equity between targets but was unsuccessful. Ultimately this participant was withdrawn from the study with ascending trend in his baseline control and alternate motor structures, descending trend in visual intervention acquisition activities, and high variability within and between targets. P1's results are available in Figure 4.

Participant 2

P2 began baseline sessions with a motor structure target of copula *be*, a visual structure target of third person singular -*s*, and a control structure of regular past tense. While visual and control structures demonstrated equivalency and either stable data or flat trend, motor structure demonstrated a steady and ascending trend. An alternate motor target of nominal possessive pronouns was substituted, and baseline was repeated successfully. P2's baseline results for his original motor target are available in Figure 5.

Acquisition Activity Data. P2's use of motor and visual structures within play activities was tracked throughout baseline, intervention, and maintenance phases. During intervention phase, his clinician actively supported the use of the target structures. Within targeted play,

motor target mean accuracy improved from 63% (standard deviation = 18.0%) to 85% (standard deviation = 11.8%) between baseline and intervention phases. Production in maintenance phase continued to improve to a final accuracy of 94% (standard deviation = 5.5%). A ceiling effect was evident in intervention and maintenance phases. Visual target mean accuracy improved from 43% (standard deviation = 13.0%) to 76% (standard deviation = 20.0%) between baseline and intervention phases. Production in maintenance phase continued to improve to a final accuracy of 88% (standard deviation = 8.4%). Notably, data variability decreased significantly from baseline through maintenance phases for both target structures. No significant change in accuracy or variability was noted on the control structure, i.e. change was well within a standard deviation of the baseline mean. P2's acquisition data are available in Table *10* and Figure 9.

Retention Probes. Following baseline, P2 completed retention probes of treated contexts for motor and visual targets in both intervention and maintenance phases. His production of his targeted motor structure demonstrated improvement from baseline with a two-session delay and a clear ascending trend throughout the intervention phase. This level of production was maintained through two weeks of maintenance but demonstrated a rapidly descending trend at the four- and six-week sessions. A ceiling effect was evident at the end of the intervention and beginning of maintenance sessions with this target, as P2 was 100% accurate in five of seven consecutive sessions. P2's production of his targeted visual structure demonstrated a small immediate shift with extremely variable data throughout the intervention phase. Intervention ended with a descending trend. Level of production was maintained the second and third maintenance sessions but demonstrated a rapidly descending trend at the four-week session. Production during the four- and six-week maintenance sessions was equal to that

of the first three baseline sessions. Data from P2's retention probes are available in Table 7 and
Figure 7.

Generalization Probes. P2 completed generalization probes in untreated contexts for
motor, visual, and control targets in the baseline and maintenance phases. Motor target mean
accuracy improved from 40% (standard deviation = 15.8%) to 94% (standard deviation = 8.9%)
and visual target mean accuracy improved from 44% (standard deviation = 15.1%) to 66%
(standard deviation = 8.9%). No significant change was noted on the control probe, i.e. change
was well within a standard deviation of the baseline mean. P2's data are available in Figure 8.

Change in Functional Use. P2's initial language sample included seven attempts at his
visual target structure of third person singular -*s*. He correctly produced five of those, for an
initial percentage of 71% correct. In his final language sample, he spontaneously generated five
attempts which were produced with 100% accuracy. Initially, P2's generated two attempts at his
motor target structure of nominal possessive pronouns. These were produced with an overall
accuracy of 100%. P2's final language sample demonstrated a continued accuracy of 100% with
a minimal increase to three attempts. P2's initial language sample demonstrated minimal, but
correct, use of his control structure, regular past tense, i.e. 100% accuracy in two opportunities.
During his final language sample, P2 maintained 100% accuracy in 12 spontaneous generations.
Changes in functional use are available in Table *10.*

Generalized Language Improvement. Overall language statistics were recorded pre-
and post-intervention. These are available in Table 11. P2 maintained stable scores in TNW,
MLU_S, and WPS. P2's change in *z*-score for TNW was 0.049, from 276 words in 50 utterances
to 279 words in 50 utterances. There was no change in MLU_S (6.28). The change in WPS was
0.041, from 5.8 words to 5.85 WPS. P2's *z*-score change in CPS measured 1.38, demonstrating

an increase well over the standard deviation for his age group. The absolute change of CPS was 1.05 to 1.23 clauses.

Participant 3

P3 began with a motor target of regular past tense -*ed*, a visual target of *do* question inversion, and a control structure of copula *be*.

Acquisition Activity Data. P3's use of motor and visual structures was also tracked throughout baseline, intervention, and maintenance phases within play activities. During the intervention phase, use of the target structures was actively supported. Within targeted play, there was a steep accelerating trend for the percent of correct responses; his motor target mean accuracy improved from 8.2% (standard deviation = 8.7%) to 50% (standard deviation = 22.6%) between baseline and intervention phases. Production in maintenance phase remained equivalent to intervention with an accuracy of 42% (standard deviation = 18.8%). Visual target mean accuracy improved from 1% (standard deviation = 2.2%) to 53% (standard deviation = 32.4%) between baseline and intervention phases, again with a steep accelerating trend for correct productions. Production during the maintenance phase declined to a final mean accuracy of 15% (standard deviation = 27.7%). Data variability was significant throughout all phases with only two overlapping data points between baseline and intervention, one on each target structure. Production of P3's control structure improved from a baseline mean of 17% (standard deviation = 14.0%) to an intervention mean of 25% (standard deviation = 22.1%) and further to a maintenance mean of 54% (standard deviation = 29.7%). P3's acquisition data are available in Table *8* and Figure 9.

Retention Probe. Baseline production in motor and visual target were stable at 0% accuracy. Baseline production for copula *be* production demonstrated a declining trend with

overall low accuracy. Following baseline, P3 completed treated context probes. No change in visual structure production was noted, as production remained at 0% flat throughout the study. Change in motor structure production began at the sixth intervention session and demonstrated highly variable production with an overall ascending trend throughout intervention (mean accuracy = 10.0%, standard deviation = 18.5). Production accuracy continued to ascend to a peak of 60% at the second and third maintenance sessions, three weeks post-intervention, then declined precipitously at both four and six weeks to create an overall production accuracy of 32% (standard deviation = 26.8) with a descending trend in maintenance. P3's retention data are available in Table 7 and Figure 10.

Generalization Probe. P3 completed generalization probes of untreated contexts for motor, visual, and control targets in baseline and maintenance phase. Motor and visual target production remained at a flat 0% accuracy throughout the study. No significant change was noted on the control probes, i.e. change was well within a standard deviation of the baseline mean. Data from P2's generalization probes are available in Figure 10.

Change in Functional Use. P3 attempted seven productions of his visual target structure regular past tense within his initial language sample. None were produced correctly. In his final language sample, P3 attempted five regular past tense verbs and achieved an improved accuracy of 60%. In his initial language sample, P3 made four unsuccessful attempts at his motor target structure of inverted question formation, although all added a *wh-* question word, e.g. "Look, where his head?" In his final language sample, P3 made achieved 50% accuracy at two attempts at inverted questions. The first attempt used a *wh-* question and was incorrectly formulated as "What that is the green playdough?" The second production matched the format of his specific targeted question inversion, and was produced correctly as "Are you calling somebody?"

Initially, P3's generated ten attempts at his control target structure of contracted and uncontracted copula *be*. These were produced with an overall accuracy of 70%, with a stark division between them: contracted *copula be* was 0% correct, while uncontracted copular *be* was 88% correct. P3's final language sample demonstrated an overall accuracy of 53%. Uncontracted copula *be* was 43% correct and contracted copula was 100% correct. Changes in functional use are available in Table *10*.

   Generalized Language Improvement. Overall language statistics were also recorded pre- and post-intervention. These are available in Table 11. P3 maintained scores within one standard deviation of his initial measurements in TNW and MLU_S, while WPS and CPS increased significantly. P3's change in *z*-score for TNW was 0.848, from 172 words in 50 utterances to 223 words in 50 utterances. The *z*-score change in MLU_S was 0.97, from 3.68 to 4.96 morphemes. Although these scores did not improve a complete standard deviation, both changes brought P3's scores within the average range for children his age. The changes in WPS and CPS were even greater. P3's change in *z*-score for WPS was 2.119, from 4.3 words to 6.97 WPS. P3's *z*-score change in CPS measured 2.13, from 0.98 to 1.21 clauses. At the post-intervention data collection, both of these scores were within average performance for children of his age.

Participant 4

   P4's target motor structure was regular past tense *-ed*. Her visual target structure was copula or auxiliary *be* statements. Her final control structure was *do* question inversion.

   Acquisition Activity Data. P4's accuracy of motor and visual target production within play-based activities was tracked through all three study phases. Both structures demonstrated a clear and immediate intervention effect, with improvements from the motor baseline mean of

21% (standard deviation = 11.6%) to 73% (standard deviation = 10.7%) and the visual baseline

mean of 18% (standard deviation = 18.8%) to 69% (standard deviation = 8.2%) in intervention.

These data reflect a notable decrease in variability within the intervention period. Although

variability again increased and a clear decrease in accuracy was evident in P4's third

maintenance session (three weeks following intervention), her accuracy rebounded such that

overall trendlines were positive for both structures. Mean production accuracy in maintenance

remained higher than baseline at 33% (standard deviation = 22.9%) for motor structure use and

68% (standard deviation = 28.4%) for visual structure use. The acquisition activity data for P4

are available in Table 8 and Figure 12.

Retention Probe. Both motor and visual accuracy demonstrated high variability and

decreasing trend in baseline phase, with mean production accuracy of 45% (standard deviation =

25.9%) and 35% (standard deviation = 37.3%) respectively. Control structure accuracy was

stable with lower variability (mean = 77%, standard deviation = 13.7%). Change in intervention

was on a consistent two-session delay with high production variability. Motor structure accuracy

demonstrated a decreasing trendline in intervention, with all data points overlapping with

baseline data. Visual structure accuracy demonstrated a shallow increasing trendline in

intervention. In maintenance, both motor and visual structure production accuracy was retained

at levels equivalent to baseline with mean production accuracy of 44% (standard deviation =

30.0%) and 36% (standard deviation = 21.9%) respectively. P4's retention data are available in

Table 7 and Figure 13.

Generalization Probe. P4 completed generalization probes of untreated contexts for

motor, visual, and control targets in baseline and maintenance phase. Although both motor and

visual target accuracy was highly variable, motor structure mean accuracy remained consistent

from a baseline 45% (standard deviation = 25.9%) to 44% (standard deviation = 11.4%) while visual target mean accuracy decreased marginally from 35% (standard deviation = 37.3%) to 18% (standard deviation = 20.5%). This level of change is within a standard deviation of the starting level. Performance on the control probe also decreased from a mean of 77% (standard deviation = 13.7%) to 58% (standard deviation = 13.0%). P4's data are available in Figure 13.

Change in Functional Use. Initially, P4 generated 17 attempts at copula and auxiliary *be*. These were produced with an overall accuracy of 24%, with a stark division between them: copula *be* was 0% correct, while auxiliary *be* was 57% correct. P4's final language sample demonstrated an overall accuracy of 32% with changes to copula *be* accuracy leading the improvement. Copula *be* finished at a spontaneous 38% correct and auxiliary *be* was 17% correct. This level of accuracy was demonstrated over 22 attempts, representing relatively stable number of attempts at this structure. P4's initial language sample demonstrated minimal but correct use of her motor structure target of regular past tense, i.e. 100% accuracy in only one opportunity. During her final language sample, P4 maintained 100% accuracy in two spontaneous generations. P4's initial language sample also included one spontaneous attempt at her control structure of *do* question inversion. She used it correctly, for an initial percentage of 100% correct. This performance was replicated in her final language sample. She spontaneously generated one attempt at question inversion which was produced with 100% accuracy. Changes in functional use are available in Table *10*.

Generalized Language Improvement. Overall language statistics were also recorded pre- and post-intervention. These are available in Table 11. P4 celebrated her seventh birthday during the intervention study, such that her scores were compared to norms for age group 6;6 – 6;11 during her initial LSA and to those of the age group 7;0 – 7;11 during her final LSA. Thus,

although her raw scores increased in half of the measurements, her performance relative to her peers was variable. P4 maintained stable z-scores in TNW, MLU$_S$, and CPS while WPS demonstrated a notable decrease. P4's TNW changed from 238 words in 50 utterances to 267 words in 50 utterances, representing a z-score difference -0.422. MLU$_S$ changed from 4.98 morphemes to 5.98 morphemes, a z-score difference of -0.04. The absolute change in WPS from 6.03 words to 5.45 WPS represents a z-score change of -1.39, indicating a significant decrease in comparison to peers. P4 demonstrated no absolute change in CPS (1.08) and showed a minimal z-score difference of -0.20.

Participant 5

P5 began baseline sessions with a motor structure target of copula *be*, a visual structure target of subject tense pronouns, and a control structure of regular past tense. While visual and control structures demonstrated equivalency and stable data with flat trend, his production of the motor structure demonstrated a clear ascending trend. Alternate motor targets of equivalent developmental level, such as plurals and third person singular *-s* were considered and probed, but due to this client's significant difficulty producing fricative sounds, the use of relative clauses was ultimately chosen as a substitute target. P5 proved responsive to initial probe following grammatical priming and baseline phase was repeated successfully, although with notable production variability. P5's baseline results for his original motor target are available in Figure 15.

    Acquisition Activity Data. P5's baseline, intervention, and maintenance phase production of target structures were tracked within play activities. During intervention phase, use of the target structures was actively supported. Accelerating trend lines were apparent for both motor intervention and visual interventions. Within targeted play, motor target mean

accuracy improved from 14% (standard deviation = 11.1%) to 55% (standard deviation = 23.1%) between baseline and intervention phases. Production in maintenance phase remained equivalent in maintenance with accuracy of 48% (standard deviation = 11.8%).   Visual target mean accuracy improved from 8% (standard deviation = 11.7%) to 54% (standard deviation = 24.7%) between baseline and intervention phases. Production in maintenance phase remained equivalent with a final mean accuracy of 55% (standard deviation = 7.7%). Data variability was significant within the intervention phase for both target structures, while production in baseline and maintenance exhibited more stability. Production of P5's control structure decreased from a baseline mean of 22% (standard deviation = 16.1%) to an intervention mean of 5% (standard deviation = 9.5%) and stabilized through maintenance with mean of 6% (standard deviation = 5.1%). P5's acquisition data are available in Table *8* and Figure 16.

Retention Probe. Following baseline, P5 completed retention probes of treated contexts for motor and visual targets in both intervention and maintenance phases. Due to clinician error, no treated context was probed for P5's motor structure in maintenance session 4. His intervention-phase production of the targeted motor structure demonstrated continued variability and no improvement from baseline. In contrast, his production of the visual target demonstrated both increased variability and increased accuracy, with a steeply ascending trend. Despite the missing data point in maintenance, immediate and stable improvement of motor target production was noted. P5's ascending visual structure trend continued through the maintenance phase. Retention data for P5 is available in Table 7 and Figure 17.

Generalization Probe. P5 completed generalization probes of untreated contexts for motor, visual, and control targets in baseline and maintenance phase. Motor target mean accuracy improved from 7% (standard deviation = 8.2%) to 42% (standard deviation = 13.0%)

and visual target mean accuracy improved from 2% (standard deviation = 4.1%) to 48% (standard deviation = 8.4%). No significant change was noted on the control probe, i.e. change was within a standard deviation of the baseline mean. P2's data are available in Figure 18.

Change in Functional Use. Due to the difficulty of creating opportunities for all of P5's target structures within a single language sample activity, spontaneous generation attempts were limited at both pre- and post-intervention administration. P5's initial language sample did not include any attempts at his visual target structure of subject tense pronouns. In his final language sample, he spontaneously generated two attempts which were produced with 100% accuracy. Initially, P5 did not generate any attempts at his final motor target of relative clauses marked with the copula phrase *that is*; however, he did demonstrate two attempts at a simple copula phrase. These were produced with an overall accuracy of 0%. P5's final language sample demonstrated an overall accuracy of 50% (2/4 opportunities) for simple copula *be*; however, P5 did not attempt production of the targeted relative clause. P5's initial language sample demonstrated no attempts at his control structure, regular past tense. During his final language sample, P5 he spontaneously produced two attempts with 50% accuracy. Changes in functional use are available in Table *10*.

Generalized Language Improvement. Overall language statistics were also recorded pre- and post-intervention. These are available in Table *11*. P5 demonstrated significant improvements in all measured statistics: TNW, MLU$_S$, WPS, and CPS. P5's TNW changed from 143 words in 50 utterances to 322 words in 50 utterances, representing a z-score difference 2.98. MLU$_S$ changed from 2.96 morphemes to 6.62 morphemes, a z-score difference of 2.77. The absolute change in WPS from 4.5 words to 6.4 WPS represents a z-score change of 1.52. P5 demonstrated an absolute change in CPS from 1.0 to 1.12, a z-score difference of 1.09.

Group Data Analysis

Effect size estimates were created using the Tau-U calculator application (Vannest et al., 2016). Effect sizes were generated for retention data during baseline and subsequent treated contexts, as well as for acquisition data across baseline and subsequent phases. Analysis of baseline trend required baseline correction for P4's motor, visual, and control retention data as well as visual acquisition data, P3's control retention data, and P5's motor and visual acquisition data. Following baseline trend corrections and phase contrasts, the weighted average Tau-U scores across participants were judged by standards provided in Chapter 3's Data Analysis section. These results are available in Table 12**Error! Reference source not found.**. Motor retention, or probe, data yielded a Tau-U of 0.4501 ($p = 0.0029$), while motor acquisition data, of use during natural activities, yielded a Tau-U of 0.6822 ($p = 0$). Visual retention Tau-U was calculated at 0.3095 ($p = 0.0351$) and visual acquisition Tau-U at 0.5939 ($p = 0.0001$). Control retention Tau-U was -0.0485 ($p = 0.7955$) and control retention Tau-U was -0.4208 ($p = 0.0051$). As expected, mixed or no effect was found within both control contexts. Motor and visual retention data yielded no clear effects. A clear positive effect was evident for the motor intervention in acquisition, or during functional activities. The Tau-U value for visual acquisition approached, but did not meet, the criterion for clear effect.

Implementation Fidelity

Fidelity to implementation procedures was measured as described within the Dependent Variables section in Chapter 3. Due to a combination of researcher error and technological failure, recordings from five of the total 72 sessions were unable to be archived. These include P2's intervention session 6, P3's intervention session 7, P4's maintenance session 3, and P5's intervention session 5 and maintenance session 2. When sessions were randomly selected for

implementation fidelity coding, the missing ones were simply omitted. The details on sessions randomly selected for each participant are provided in Table 13. Overall, study fidelity was measured at 85%, reflecting 88% in baseline, 90% in intervention, and 76% in maintenance phases. Analysis by participant indicates a range of 73% to 96% accuracy for each graduate student participant – child pair. The breakdown for each pair in total and across phases is available in Table *14*. Separation of fidelity by intervention type demonstrates no significant difference between the two. Fidelity for motor intervention procedures was measured at 89%, while those for visual intervention procedures was 91%. Separation of fidelity by order of activity also demonstrates no significant difference. Fidelity for intervention procedures in the first activity block was measured at 88% and that for the second activity block was 91%.

Social Validity

Social validity data were gathered from both parent and graduate student participants by questionnaire on the final maintenance session of the study. Items were rated on a 5-point Likert scale, with 1 = Strongly Disagree and 5 = Strongly Agree. Average scores for parent participants by question are available in Table *15*. In general, parents strongly agreed that their child benefitted from the intervention. They did not appear to specifically notice if their children used the gestures to produce grammar structures (average score = 3), but were slightly more confident that the children referenced the visual intervention's shapes and colors (average score = 3.6). Parents agreed that their child's grammar production improved overall (average score = 4.4), that they would recommend specific visual or tactile-kinesthetic grammar intervention (average score = 4.8), and that they would like to learn more about the interventions provided (average score = 4.5). Two of the four responding parents indicated that they preferred the visual intervention modes because their children referenced them more often than the movements. One parent

reported no preference between the interventions and did not indicate a reason for their ambivalence. One parent indicated that they preferred the tactile intervention mode because it was easy to do and required no special equipment. This parent also noted that their child did better with active therapies.

Graduate student participants unanimously agreed that their child participants benefitted from the intervention (average score = 4.0) but were slightly less confident that grammar specifically improved (average score = 3.3). Their clients were reported to use both intervention modalities (average score = 3.7), although there was higher variability in reporting the client use of gestures (range 2 – 5) than shapes and colors (range 3 – 4). One clinician specifically noted that although the client's mother reported the client's spontaneous use of the visual intervention techniques at home, he was observed spontaneously using the motor actions, or gestures, for self-correction in his final maintenance session. Two of three responding graduate student participants preferred the tactile-kinesthetic intervention. One of these noted that it was easier for her to provide the visual shapes and that her child participant would refer to them, but that as the interventions continued, the child participant used gestures more frequently. The other clinician who preferred tactile-kinesthetic interventions referenced her client's level of activity and enjoyment of movement. She indicated a belief that the most effective "modality is client dependent."

Graduate student participants agreed that they ended the study feeling confident in their ability to provide intervention for grammar challenges (average score = 4.3). They were more confident that they had learned appropriate methods for doing so (average score = 4.7) and would use what they had learned again (average score = 4.7). They all strongly agreed that participation in the project was worth their time and effort (average score = 5). One participant

expressed gratitude for the opportunity to participate, indicating that it had been an enjoyable clinical experience. Another reiterated the value of the techniques learned and noted additional clinical learning in flexibility through the study experiences. Average scores for graduate student participants by question are also available in Table *15*.

Reliability

To reduce coder confusion, those sessions randomly-determined for implementation fidelity coding were also coded for reliability. Again, details of this selection are available in Table *13*. Due to a combination of researcher error and technological failure, recordings from some sessions were unable to be archived. These include P2's intervention session 6, P3's intervention session 7, P4's maintenance session 3, and P5's intervention session 5 and maintenance session 2. When sessions were randomly selected for coding, the missing ones were simply omitted. Inter-assessor agreement was assessed statistically for consistency with intraclass correlations derived from the percentage of grammatical targets correct in acquisition as well as retention data. In accordance with procedure, as described in the Dependent Variables section of Chapter 3, ten largely variant data pairs within five participant sessions were recoded to verify accuracy. The final ICC value was computed at 0.90, indicating reasonable reliability for a clinical study.

Discussion

The purpose of this study was to investigate the use of two different intervention

techniques to increase the use of grammatical structures by children with DLD. Both

intervention models used the auditory-verbal models present in existing empirical studies and

clinical practice but differed in the paired sensory input provided. In this chapter, results of the

study will be reviewed with specific reference to these original research questions. Research

questions will be restated and then discussed singly. Final comments on the limitations to this

study, the addition to the existing literature, implications for educational practice, and

implications for future research will complete the document.

Intervention Effects

Research Question 1: Is there a functional relation between language interventions that

pair verbal support with a) systematic visual or b) systematic motor with the use of grammatical

structures by children with developmental language delay (DLD)? For the sake of brevity,

results of interventions pairing verbal with systematic visual supports will be referred to as visual

outcomes. Those outcomes that measure rate of learning within single sessions will be referred

to as acquisition data. Those outcomes that measure learning retention across sessions will be

referred to as retention data. Therefore, the outcomes measuring rate of learning within

interventions pairing verbal with systematic visual supports will simply be termed *visual*

acquisition outcomes. This pattern will also apply to those interventions pairing verbal support

with systematic motor supports, such that outcomes measuring learning retention across sessions

will be termed *motor retention outcomes*. Acquisition data was attained in natural play activities.

Retention data was attained through use of structured probes with visual elicitation aids.

Maintenance and generalization outcomes will be addressed within a separate section of this

chapter. Finally, the corporate effects of intervention for acquisition and retention will be briefly stated.

Visual Acquisition Outcomes. Visual analysis of all participants' visual acquisition outcomes indicates consistent positive change with a single-session delay in the intervention phase. For all but one of the four participants (P3), use of correct grammar targets maintained at an improved level. The weighted average Tau-U for visual acquisition outcomes does not quite reach the level of a clear effect. It is notable that data during visual acquisition activities tended to be highly variable across participants, particularly as phase changed from intervention to maintenance. This variability is likely to have rightfully lowered the generated Tau-U from the improvement noted in visual analysis, which demonstrated a logical consistency in overall intervention outcome.

Visual Retention Outcomes. The visual analysis of visual retention outcomes indicates no change for two of four participants (P3 & P4), a small positive shift from baseline to intervention phase for one participant (P2), and a larger positive shift for the final participant (P5). The weighted average Tau-U for visual retention outcomes confirms no clear effects in the participant group. The child participants who demonstrated a positive retention shift in the current study were male and demonstrated a mild to moderate impairment in grammar specifically. These two participants had no other demographic characteristics in common. The participants who did not show response to the visual intervention within retention data shared a severe delay in grammar and a medical diagnosis of ADHD (See Table 5, Table 6, & Table 7).

Motor Retention Outcomes. Visual data analysis depicts a clear functional relationship between intervention and motor retention outcomes for one of four participants (P2). Another one of the four participants (P3) demonstrated a shallow ascending trend for retention following

motor intervention. One of four (P4) demonstrated a shallow descending trend, and the final

(P5) demonstrated no significant change. These results are supported by the Tau-U ratings of no

or mixed effects. Those participants who showed improvement in motor retention outcomes

were both male but shared no other demographic characteristics. Those participants who

demonstrated no or mixed effect began the study with overall language and receptive language

scores within normal limits (See Table *5*); no other similarities were apparent.

Motor Acquisition Outcomes. The functional relation between intervention and motor

acquisition is both clear and positive. Increases in production accuracy occurred with a

consistent two-session delay for all four participants. Two of four participants (P4 & P5)

decreased their production accuracy gradually over the six-week maintenance period; however,

two of four participants (P2 & P3) were able to maintain the increase in accuracy within a

standard deviation through the six-week maintenance period. The Tau-U score for motor

acquisition data confirmed a clear intervention effect. The two participants who maintained

production of grammatical targets within natural activities were the same two who shared

positive trends in retention probes. The only shared characteristic was gender. Those

participants who had difficulty maintaining their achieved intervention accuracy were those who

began the study with overall language and receptive language within normal limits (See Table 5).

Functional Grammar Improvement. Overall effect sizes for grammar improvement

were established by creating averages for *z*-score changes across participants between their initial

and final language sample. Participants averaged 0.86 standard deviations of improvement in

TNW, indicating growth well beyond expectations for 8 intervention sessions. MLU_S *z*-score

average improvement was 0.93, almost a full standard deviation of change. Change in WPS

averaged 0.57 standard deviations, indicating that participants used slightly more words within

each sentence generated. However, CPS demonstrated an average increase of 1.1 standard deviations. This shows that although the sentence length changed a bit, participants routinely used much more complex grammar. Across all participants, strong positive effects were found in functional grammar use in natural contexts for TNW, MLU$_S$, and CPS. A moderate effect was evident for WPS.

Conclusion. In response to the first research question (See page 82), a clear moderate functional relation between intervention and outcome is confirmed in motor acquisition activities, i.e. practice in age-appropriate activities using verbal and systematic motor supports. However, statistical analysis also supports the limited functional effects in visual acquisition activities, i.e. practice in age-appropriate activities using verbal and systematic visual supports, as well as motor retention learning, i.e. use of target structure from practiced contexts in a structured probe. The outcomes for visual and motor intervention outcomes are notably different from those of control structures. Control structures showed no improvement in acquisition activities across participants and no improvement for three of four participants in percentage of accuracy during natural language use. Therefore, there appears to be a moderate-to-strong functional relation between generalized use of more expressive language and more complex grammar across the group.

Intervention Modality Impact on Rate of Learning

Research Question 2: Does the rate at which children with DLD learn grammatical structures differ between language interventions that pair verbal support with a) systematic visual or b) systematic motor? Visual and motor acquisition and retention outcomes were analyzed.

Speed of Learning. The first aspect considered was the speed of learning, or how soon in the intervention phase acquisition or retention data crossed the average baseline value for each

participant. Motor acquisition data crossed the mean baseline value in the first intervention session for all participants (average = 1.00 sessions). Visual acquisition data generally crossed the mean baseline value in the first intervention session (average = 1.25 sessions). Motor retention data generally crossed the mean baseline value by the third intervention session (average = 3.50 sessions). Visual retention data crossed the mean baseline value in the second intervention session (average = 2.00 sessions), but one participant never improved visual retention beyond baseline.

Magnitude of Learning. A second analysis was the magnitude of change. Change from highest baseline point to highest intervention point and average change across baseline to intervention phase were both reviewed. Motor acquisition outcomes demonstrated a highest point change of 69.5% (P3) and an average point change of 40.3%. Visual acquisition outcomes demonstrated a highest point change of 85.0% (P3) and an average point change of 46.4%. Motor retention outcomes demonstrated a highest point change of 40% (P3) and an average point change of 10.7%. Visual retention outcomes demonstrated a highest point change of 20.8% (P5) and an average point change of 8.0%.

Conclusion. The analysis of data above matches the impression from visual inspection. Generally, both motor and visual acquisition outcomes were faster and greater than those obtained from retention probes. The slightly greater magnitude of learning from visual intervention methods falls within the standard deviation of the scores; the slight advantage in speed of learning from motor intervention methods is also negligible. There is also no difference in rate of learning between sensory modalities in retention in treated contexts. Thus, using paired verbal and systematic motor interventions may result in better rate of learning for production in natural activities. This benefit is unlikely to appear in drill contexts, such as probes.

Intervention Modality Impact on Maintenance and Generalization

Research Question 3: Does the sensory modality pair used within language interventions impact the generalization and/or maintenance of use of grammatical structures by children with DLD? Those outcomes that measure maintenance of targeted grammatical contexts and generalization of grammatical structures to structured probes will be discussed. The first will include treated context data and untreated context data. As noted in Methods, both data sets were captured through structured probes with visual elicitation aids. The generalization of grammar improvement into natural language contexts will be referred to as generalization measures and consist of natural use of target structures and general grammatical language improvement measures.

Motor Maintenance. Three of four participants maintained motor acquisition outcomes within one standard deviation of their intervention mean in their maintenance phase (P2, P3, & P5). P4 demonstrated a precipitous decrease in motor acquisition accuracy in maintenance session 2. P2 maintained motor retention outcomes, while P3 and P5 improved motor retention outcomes beyond one standard deviation of their intervention mean. P4 demonstrated no change in retention outcomes across any phase change. P4 was the oldest study participant

Visual Maintenance. Three of four participants maintained visual acquisition outcomes within one standard deviation of their intervention mean in their maintenance phase (P2, P3, & P5). P2, who did not maintain accuracy in visual acquisition data, began the study with the largest degree of overall language impairment and was the only participant with a documented receptive language impairment (See Table 4, Table 5, & Table 6). This participant also began the study with ratings below age expectations in all areas of the BRIEF and was the youngest participant by one month. Two of four participants maintained accuracy in visual retention

outcomes (P2 & P4). P5 continued to demonstrate significant improvement from intervention to maintenance, while P3 demonstrated no change in visual retention outcome across any phase change. Those participants who maintained visual retention outcomes were the older child participants and the two who scored appropriately for their age on the BRIEF (See Table 4 & Table 6). The nonresponsive participant was the youngest and showed most severe language deficits. The participant who responded to visual interventions, but did not maintain retention outcomes was unique in his split executive function results: behavioral regulation skills were above criterion, but metacognition skills were below criterion (See Table 4, Table 5, and Table 6). It is possible that his specific difficulty with working memory, organization, and monitoring impacted his ability to maintain skills in the context-free probe that measured visual retention.

      Motor Generalization. Generalization of motor target structures was assessed through comparison of baseline data to data from probes of untreated context administered in maintenance phase (Table *9*) and through production spontaneously within language samples (Table *10* & Table 11). Two of four participants showed improvement in motor generalization probe outcomes (P2 & P5). The other two participants demonstrated production equality in baseline and generalization measurements (P3 & P4). The two child participants who did not demonstrate ready generalization shared a previous ADHD diagnosis and no other demographic characteristic.

      Within a natural speaking context, two of four participants improved their accuracy of target structures (P3 & P5) and the remaining pair increased their number of target attempts by one each (P2 & P4). Those participants who increased their number target attempts could not show growth in accuracy, due to initial use measured at 100% correct. They both demonstrated stable performance in total number of words (TNW), length of utterance (MLU_S), and sentence

length (WPS) in play language sample. P2 demonstrated a significant improvement in sentence

complexity (CPS). Although P4's language sample raw scores increased, a change of norm

groups based on her age pre- and post-intervention resulted in stable *z*-scores. However, the

participants who demonstrated accuracy increase in motor target structures in a play language

sample also showed significant generalized improvement in sentence length (WPS) and

complexity (CPS). These participants were the two youngest of child participants, at the ages of

4 years 7 months and 4 years 8 months at the beginning of the study. They also demonstrated the

lowest overall scores on the BRIEF (See Table 6).

Visual Generalization. Generalization of visual target structures was assessed through

comparison of baseline data to data from probes of untreated context administered in

maintenance phase (Table 7) and through production spontaneously within language samples

(Table *10* & Table 11). In generalization probe outcomes, the same two of four participants who

improved motor probe outcomes improved with the visual modality. Again, both child

participants had a previous ADHD diagnosis.

All four participants improved their accuracy of target structures and two of four

participants increased the number of spontaneous target production attempts (P4 & P5). Those

participants who showed growth in attempts and accuracy were the two participants who

demonstrated only a mild expressive language delay and global language ability within normal

limits at initial assessment. They shared no other exclusive demographic characteristics (See

Table 4, Table 5, & Table 6). As mentioned in the Motor Generalization section above, three of

four participants demonstrated stable performance in TNW and MLU$_S$ in play language sample.

P4's standardized results were stable, while her raw results demonstrated increases in number of

words (TNW), length of utterance (MLU$_S$), and sentence complexity (CPS). Her length of

sentence (WPS) demonstrated a significant decrease from baseline to maintenance phase. P2 generalized grammatical improvement to sentence complexity (CPS), P3 to sentence length and complexity (WPS & CPS), and P5 to all statistics across the board. In comparison to children their age, two of four participants (P3 & P5) ended the study with all language sample measurements within normal limits. These were the same participants who demonstrated accuracy increase in motor target structures in the final language sample, were the two youngest of child participants, and earned the lowest scores on the BRIEF.

     Conclusion. Most child participants maintained both motor and visual acquisition accuracy in the maintenance phase; half of the child participants continued improvement in motor retention outcomes through the maintenance phase. Only one child demonstrated continued improvement in visual retention outcomes in that phase. In probe tasks of generalization, half of the child participants demonstrated improvement with both their motor and visual target structures. In natural language tasks of generalization, all four participants improved either their percentage of accuracy or their number of attempts at targeted motor structures, as well as their percentage of accuracy for targeted visual structures. Half of child participants also increased their number of attempts at targeted visual structures. Based on this analysis, maintaining improvement in contextualized practice does not depend on the sensory modality of intervention. However, continuing improvement and generalizing improvement in decontextualized tasks are slightly more likely when using motor sensory intervention supports. This pattern of learning was also reported within two studies where continuing improvement and generalization were demonstrated from a complexity-based intervention for morphological development (Owen Van Horne et al., 2018, 2017). Children with lower executive functioning abilities may also be more receptive to motor supports. Improvement in functional use is more

likely when using visual sensory intervention supports, particularly with children who are more mildly impaired.

Viability of Intervention

  Ease of Implementation. Research Question 4 addressed the ultimate usability of motor and visual interventions by asking: Are novice clinicians able to implement both interventions with fidelity? Three of four graduate clinician participants achieved an average fidelity greater than 84% across phases of these interventions. The graduate clinician participant with the lowest scores was able to maintain a 73% average across phases. This graduate clinician was paired with child participant P4. It is possible that P4's lack of improvement in retention and generalization probes and limited improvement in acquisition and natural language tasks results from her clinician's lower implementation fidelity. It may also be of note that this was the treating clinician's first clinical experience and the child participant had a severe articulation delay related to a repaired cleft palate, demonstrated severe expressive language delays, and had a diagnosed attention deficit hyperactivity disorder. Most clinicians will agree that this is a challenging client for any first-time clinician.

  Fidelity can also be judged within only the critical intervention phase. Here, the graduate student clinicians yielded an average of 90%, the highest fidelity percentage by phase. The most common error in procedure was forgetting to thank the child for his or her effort during the session. As most participants demonstrated moderate-to-strong improvement in grammar use during natural communication, it appears that 90% fidelity is sufficient to demonstrate improvement across an 8-session intervention. Therefore, while each graduate clinician participant could continue to improve, as a group, they implemented both interventions with adequate fidelity.

Intervention Value to Clinicians. Research Question 5 addressed the viability of motor and visual interventions by asking: Did the clinicians using language interventions that pair verbal support with a) systematic visual or b) systematic motor find these intervention strategies useful and effective when teaching grammatical structures to children with DLD? As noted in Chapter 4, Social Validity, the clinicians agreed unanimously that their child participants benefitted from the grammar intervention and they would use it again. They were slightly less certain that their paired child participants used the movements or colors and shapes they were taught to facilitate appropriate grammar use in everyday life. This seems reasonable, since the graduate student clinicians were not present during most of their paired child participants' daily routines. However, all clinicians strongly agreed that learning the paired verbal-visual and verbal-motor support techniques were worth their time and effort.

The involvement of novice clinicians also seemed to benefit the clinician directly. All responding graduate student participants agreed that they learned appropriate intervention techniques and feel confident in their treatment of impaired grammar. One commented that she also learned how to be flexible in session scheduling, while another appreciated the first-hand observation of research design implementation and completion.

Intervention Value to Parents. Research Question 6: Did the caregivers of children receiving language interventions that pair verbal support with a) systematic visual or b) systematic motor find the intervention strategies useful and effective for teaching grammatical structures to their children with DLD? Parents strongly agreed that their children benefitted from the interventions provided and would recommend the interventions. They agreed less strongly that their children's grammar improved noticeably and that they would like to continue in the intervention program. Two of four responding parent participants preferred the visual

intervention supports while one preferred the motor supports. Their preferences seemed to directly reflect which type of support they saw their child using at home. However, it should be noted that the parent who preferred the motor-based supports was the only parent who observed the treatment sessions through live-time video observation. The other parents were not trained in recognizing systematic motor actions, in this case, specifically gestures. Their preferences for visual intervention supports may simply reflect the familiarity of shapes and colors.

Conclusions. Both the existing Shape Coding™ and the new equivalent systematic motor interventions appear viable for more widespread use. While individual novice clinicians could stay more faithful to the intended intervention procedures, as a group, they implemented both interventions with adequate fidelity. The clinicians also saw value in both types of interventions and recognized potential power in combining them. Parents also reported value to both types of interventions and agreed that they benefitted their child and improved his or her grammar use.

Connections and Additions to Existing Literature

Combined Explicit and Implicit Techniques. The learning that resulted from the combination of explicit and implicit intervention techniques supports are similar to the results of Calder et al. (2018) who report that two of three children made significant improvement in grammar in standardized tests and functional use using Shape Coding™ techniques combined with implicit approaches to intervention. A study by Smith-Lock et al. (2013) found that although explicit and implicit techniques for grammar intervention demonstrated a very strong effect (Cohen's $d = 1.66$), the treatment was more successful in children without articulation difficulties. They theorized that articulation difficulties interfered with the production of specific grammar targets. It is possible that the lower intervention effect sizes found in this study are a

result of comorbid articulation delay in all the child participants, despite the strategic selection of grammatical targets that did not overlap articulation omissions or distortions.

Connections to the Literature. Results from the current study align with many outcomes in the existing literature. For example, retention outcomes of P2 and P4 are consistent with the results of similar interventions using Shape Coding™ (Kulkarni et al., 2014), whose two participants demonstrated improvement within the intervention phase with significant effects sizes only being reached at the end of 10 weeks of treatment. The success of a multiple modality intervention that included tactile and motor stimuli replicates the success of MetaTaal, a Lego brick-based intervention (Zwitserlood et al., 2015). Zwitserlood et al. (2015) suggested that such interventions, which reduce the literacy demands upon children, can be more available to children with language impairments who often have literacy difficulties as well. The success of the current interventions supports this statement, as neither Shape Coding™ nor the systematic motor actions developed for this study required literate sound-symbol knowledge. Instead, they both reflected the phonemic production of targeted grammar structures. Combinations of phonology and morphosyntactic interventions have been reported to be successful for expressive communication improvement in another small *n* study (Feehan et al., 2015). Control structure results in this study confirm that children do not improve response accuracy or functional use of morphological structures not specifically targeted (Eidsvåg Sunniva et al., 2019; K. M. Smith-Lock et al., 2013).

Additions to the Literature. This study is the first to directly compare visual outcomes and motor outcomes. In natural activities, a slight learning advantage to paired verbal and systematic motor supports is suggested. This is important for ultimate outcomes in children with DLD, particularly in view of the findings of Hsu & Bishop (2014) which indicate that memory

span predicts grammar learning for these children. The visual and motor maintenance outcomes of this study also demonstrate differentiation by level of executive functioning and ADHD diagnosis. It is worth noting that participants sharing an ADHD diagnosis experienced clear difficulty in generalizing use of the target structures in decontextualized tasks, e.g. probes. This implies that the use of decontextualized tasks for assessment may not reflect the true functional learning of students with ADHD. However, production accuracy continued to improve, and outcomes were mitigated when interventions including systematic motor learning techniques were used. Another logical conclusion is that younger students, particularly those with lower language and lower overall executive skill function may see more benefit from interventions that include systematic motor learning techniques than those with only verbal and visual supports.

The question of mechanism for the slight advantage of naturally paired verbal and motor supports remains. Research by Hilliard (2016) demonstrates that motoric actions, in the form of hand gestures, have a direct impact on the neurological mechanism of memory. Hostetter & Mainela-Arnold (2015) note that such actions may communicate knowledge that is understood but not yet linguistically encoded. Because automatic task performance may depend upon psychomotor abilities (Hubert et al., 2007), the use of motor as an intervention may supplement emergent linguistic knowledge to reduce task demands on children with DLD. Certainly, the results of (Toumpaniari et al., 2015)'s study of vocabulary learning with natural and systematic motoric representations also supports the positive impact of interventions including a motor component.

As a final note, the results of this study suggest that the planned and consistent use of contextualized tasks, e.g. natural speaking activities, may have a positive impact on generalization of targets and generalized language improvement in both productivity and

grammaticality. The use of natural language activities for systematic skill practice is in accordance with the evidence-based suggestions made by (Kamhi et al., 2014). The incorporation of variable individual targets within consistent target structures is supported for learning throughout the motor learning literature and supported within some language learning studies (Owen Van Horne et al., 2017, 2018). The variable targets is an inherent feature within consistent use of natural practice opportunities, which in turn allow enhanced child attention and motivation. Intrinsic motivation and attention have also been recognized as essential complements to motor learning principles (Maas et al., 2008; Wulf & Lewthwaite, 2016).

Limitations of the Study

Single subject research designs allow demonstration of causality but are limited in ability to identify differences between individual participants vs differences generalizable to the general population. This is true of the current study. Therefore, any conclusions drawn about individual participant characteristics and the intervention outcomes will benefit from confirmation. The close attention to participant characteristics of comorbid disorders and relative severity enables the reader to understand the specific combinations of child characteristics and potential outcomes of both intervention types. Child executive function abilities were measured in this study with the BRIEF. Although the BRIEF is a valid and reliable measurement tool, it relies on parent report and may not reflect underlying neurological realities. Currently, there are few ways to directly measure the executive function abilities for young children. This lack may impact outcome interpretation. There is a corresponding difficulty quantifying comorbid diagnoses which may also impact interpretation. The current study addressed this by combining the severity levels of language impairment as designated by standardized assessments with subjective determinations from both graduate clinician participants and the doctoral researcher.

Although attempts were made to reduce the impact of measurement limitations, there is no way to truly know their effect.

Other limitations became obvious throughout the course of the study. First, all results should be interpreted with caution in view of the relative nonresponse in Participant 4. In the case of P4, her parent confirmed self-correction of targets at home. Both the researcher and the graduate student clinician felt that P4's difficulty with sustained attention may have limited her response to both interventions. Therefore, her intervention was modified to include the combined use of motor, visual, and verbal interventions and continued, with parent permission. This modified study has not been completed and the results will be reported in a future manuscript. A further threat to reliability and implementation fidelity was data loss due to malfunctions in the technology used to record intervention sessions. This threat was mitigated by completion of the planned percentage of second codings by substituting randomly selected sessions for those lost to technological malfunction. The number and type of outcome measurements, which included immediate learning, delayed recall in both probes and natural activities, as well as specific and generalized language improvement, significantly added to the complexity of clear documentation and interpretation. Close review of existing literature was completed to allow comparison to similar outcome measures. Finally, unknown sources of error may have had unknown effects on the study outcomes.

Implications for Educational Practice

The original desire for this study was to provide answers for interventionists. Individuals addressing grammar learning in children with DLD may note the importance of assessing the value of individual and combined sensory supports. Different children may benefit from different modes of support. However, interventions can be confident that they should combine

implicit and explicit methods of instruction and practice in natural contexts for skill

generalization. Implications to be considered include that children with severe grammar delays

and ADHD/executive function challenges may derive more benefit from paired verbal and

motor-based supports, such as gestures. Children who demonstrate milder overall language

delays may respond better initially to combined verbal and visual supports. In any intervention,

different sensory modes of support implemented inconsistently or without conscious intent may

create unexpected impacts on potential outcomes. Thus, interventionists such as teachers and

related service providers need to be carefully considerate in intervention implementation.

Suggestions for Future Research

Needs for further research are evident from the discussion of the current study. First,

confirmation of these results and replication within a larger scale (RCT) is necessary.

Specifically, further investigation into differential response patterns, with increased n to provide

power to generalizations, would be beneficial to clarify conclusions. Another suggestion is that

clear documentation of multisensory intervention procedures should be included not just within

the research process but also in the publication of results. Specific details of sensory input used,

alone or in combination, provides valuable information. With incomplete knowledge of sensory

input for a therapeutic technique, we run the risk as a profession of overlooking potential impacts

on intervention outcomes.

Finally, further research should be considered for its ability to bridge our knowledge into

practice. Many studies are confined to homogenous participants for theoretical reasons.

However, quality information is also needed for the heterogeneous population that exists in

today's schools. We need to support our professionals in use of effective and efficient teaching

techniques with their "real" children, who demonstrate a variety of comorbid diagnoses and

compounding factors.

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TABLES

Table 1*: Summary of Shape Coding Evidence*

Study	Experimental Design	Sample Size	Outcome Measures	Population (years)	Setting
Ebbels and van Der Lely (2001)	QE – WP	4	Probe	11 - 12	School 1:1
Ebbels (2005)	RCT	27	Probe	11 – 16	School 1:1
Ebbels (2007)[a] (1)	SSRD	3	Probe	12 – 14	School 1:1
(2)	SSRD	2	Probe	12 – 14	School 1:1
(3)	SSRD	9	Task	11 – 13	School Classroom
Ebbels et al. (2007)[b]	RCT	27	Probe	11 - 16	School 1:1
Bolderson et al. (2011)	SSRD	6	Formal & Probe	5 – 6	School 1:1
Kulkarni et al. (2014)	QE – WP	2	Probe	8 - 9	School 1:1
Ebbels et al. (2014)[c] (1)	RCT	14	Formal & Probe	11 - 16	School 1:1
(2)	QE – WP	14	Probe	11 - 16	School 1:1
Engman (2017)	SSRD	2	Task	5 - 6	Clinic 1:1

Note: QE = quasi-experimental, WP = within participants, pre- & post-test, RCT = randomized controlled trial, SSRD = single subjects research design. [a] This article reports a series of related SSRD experiments which are disaggregated in this summary. [b] This article is nearly identical to Ebbels (2005) reported above. One appears to be a report for U.K. audiences, and one for U.S. audiences.

[c] This article reported an RCT, with follow-up QE study for non-responders which are disaggregated in this summary.

Table 2: *Summary of Study Characteristics*

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
Balthazar and Scott (2018)	30	10;0 – 14;11	Specific Language Impairment	Understanding complex sentences with adverbial and relative clauses and object complements	Dose	1:1 SLP; 40-60 min once per week compared to 40-60 min twice per week over 9 weeks	Clinically significant with medium to large effect sizes on one treatment target with 80% of participants.
Bredin-Oja and Fey (2014)	5	2;6 – 4;3	Expressive Language Delay	Production of grammatically complete semantic relations	Grammatical vs. telegraphic models	1:1 SLP; 20-30 min once or twice per week for 7 sessions	Use of grammatical morphology within targeted semantic relation more often with grammatical models. The result was visible and significant for 60% of participants.
Calder et al. (2018)	3	6;2 – 7;0	Developmental Language Disorder	Understanding and production of regular past tense -*ed*, third person singular -*s*, and possessive *'s*	Paired explicit instruction with implicit hierarchical cuing	1:1 SLP; 45 min twice per week for 5 weeks	Two of three participants improved to age-appropriate grammar understanding; Expressive results showed statistical

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
							significance for all three participants and mixed clinical significance across participants and targets
Curran and Owen Van Horne (2019)	7	4;0 – 6;3	Expressive Language Delay	Production of causal adverbials	Recasts for causal adverbials; Intervention embedded in science lessons	1:1 SLP; 40 – 60 min once or twice per week or twice per two weeks for 20 sessions	Production of *because* targets improved for 6 of 7 participants. No or small effect sizes for those with lowest performance at baseline; moderate to strong effects for those with emergent baseline performance. No benefit with *so* targets.
Eidsvåg Sunniva et al. (2019)	20	4;8 – 6;7	Developmental Language Delay	Production of grammatical morphemes, including third person singular -s, pronoun *she*, auxiliary *is*, and	Individual treatment vs group of two treatment	1:1 SLP or 1:2 SLP; 30 min daily for 5 weeks	Clinically significant response for 70% of participants, with minimal practical difference between delivery models.

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
				regular past tense -*ed*			Participants in small groups did not learn their partner's treatment targets.
Feehan et al. (2015)	2	6;7	Speech and Language Delay; Autism Spectrum Disorder	Production of correct argument components and grammatical morphemes	Alternating unitary treatment blocks (morphosyntax and phonology)	1:1 SLP; 60 min once per week for eight weeks	Overall improvement in productivity, MLU, lexical diversity, and syntactic completeness for both participants
Finestack (2018)	25	5;6 – 8;1	Developmental Language Disorder	Production of novel grammatical targets	Implicit only vs. paired explicit and implicit instruction	1:1 computer teaching; 20 min sessions once daily for up to five days	Paired explicit and implicit instruction was more effective in acquisition, maintenance, and generalization.
Hsu and Bishop (2014)	28	6 – 11	Specific Language Impairment	Understanding of reversible sentences including spatial prepositions	Unique sentences with variable nouns vs. sentence set with repeating nouns	1:1 Computer based game training; 5-7 min once daily for four to six days	Children appear to rely on repeated contexts for initial learning, then extract and generalize to new contexts such that equal learning was achieved over the

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
							four training sessions.
Kulkarni et al. (2014)	2	8;11 and 9:4	Language Disorder and Autism Spectrum Disorder	Production of regular past tense -ed	Activities to improve generalization	1:1 SLP; 30 min ten sessions over one school term (one participant repeated seven 1:1 sessions with a teaching assistant)	Both participants significantly improved use of past tense in intervention, but only one improved in conversation with generalization activities. The other participant improved conversational production without the generalization activities.
Meyers-Denman Christina and Plante (2016)	16	4;10 – 5;10	Specific Language Impairment	Production of grammatical morphemes, including present progressive verbs, third person singular -s, past tense -ed, and more	Efficacy and dose schedule of Enhanced Conversational Recast treatment	1:1 SLP; 30 min in one session vs 10 min in three sessions within four hours daily over five weeks	Both dose schedules resulted in statistically significant change with no difference in effect or retention at approximately two months

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
Owen Van Horne et al. (2018)	20	4;0 – 10;0	Developmental Language Disorder	Production of regular past tense -*ed*	Comparison of easy vs. difficult complexity levels for target verbs	1:1 SLP; variable min in once-thrice per week from 13 – 36 sessions	Children whose treatment contexts were more difficulty demonstrated higher accuracy levels following intervention, and levels maintained and generalized the target through eight weeks post-therapy. No generalization was noted across morphemes.
Owen Van Horne et al. (2017)	18	4;0 – 8;11	Developmental Language Disorder	Production of regular past tense -*ed*	Comparison of easy vs. difficult complexity levels for target verbs	1:1 SLP; variable min for 12 – 36 sessions	Clinically and statistically significant greater improvement in accuracy and generalization in the difficult condition; 4/18 participants made minimal to no gains across conditions

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
Phillips (2014)	197	3;4 – 8;5	At-risk for Reading Disorders; Language Delay associated with Low SES	Understanding and production of syntax structures	Classroom assistant delivered small group intervention	4:1 teaching assistant; 20 min daily, four days a week for three weeks	Statistical significant change in 10/16 possible groups, with effect sizes ranging between small to very large.
Plante et al. (2014)	18	4;0 – 5;11	Specific Language Impairment (1 participant with comorbid ADHD)	Production of grammatical morphemes, including present progressive verbs, third person singular -*s*, past tense -*ed*, and more	Small number of repeated examples recast vs. large number of different examples recast	1:1 SLP; 30 min once daily for 24 sessions	Statistically significant change in both probes and unique spontaneous productions with high-variability condition
Ramirez-Santana et al. (2018)	34	5;7 – 11;4	Specific Language Impairment	Production of grammatical sentences, morphemes, and syntactic structure	Narrative and morphosyntactic exercises in combination	1:1 SLP; 40 min twice weekly for 216 sessions (3 school years)	Statistically significant gains in all targets, with large effect sizes
Shahmahmood Toktam et al. (2018)	10	5;11 – 7;9	Primary Language Impairment	Production of complex and grammatical sentences	Efficacy of response to working memory vs. grammar tasks	1:1 SLP; 60 min thrice weekly for 15 sessions	Statistically significant improvement in grammatical functioning for all participants, with

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
							clinically significant improvement for 4-7 of 10 participants
Smith-Lock (2014)	5	5;2[a]	Specific Language Impairment	Production of regular past tense -ed	Behavioral support for single- or dual-mechanism grammar theory	1:2/3 SLP, Teacher, or Assistant; 45 min once weekly for 8 weeks	Significant improvement on treated and untreated past-tense items for 5/5 participants
Smith-Lock et al. (2015)	31	5;0 – 5;11	Specific Language Impairment	Production of possessive -s, regular past tense -ed, third person singular -s	Recast + cueing vs Recast only	1:12, then 1:2/3 SLP, Teacher, or Assistant; 45 min once weekly for 8 weeks	Greater improvement with recast + cueing treatment at end of intervention; differences did not maintain nor generalize
To Carol et al. (2015)	52	6;0 – 11;11	Developmental Language Disorder[b]	Production of relative clauses, connectives, prepositional phrases and embedded clauses	Comparison of sentence-combining trial training vs narrative language intervention	1:1 SLP; 35 min twice monthly for 8 sessions	Statistically significant and comparable improvement in grammar and syntax with both types of intervention

Study	Number of Participants	Age	Diagnosis	Grammatical Target	Experimental Aspect	Delivery Model, Dose Frequency, and Duration	Results
Zwitserlood et al. (2015)	12	9;3 – 12;8	Specific Language Impairment	Understanding and production of relative clauses	Inclusion of motor and tactile/kinesthetic components	1:1 SLP; 30 min twice weekly for five weeks	Statistically significant improvement in production, but not understanding, was achieved and maintained

Note. [a]Smith-Lock (2014) provided only the mean age of 5 years, 2 months (standard deviation = 3 months, 7 days). [b]To

Carol et al. (2015) did not describe their participants as DLD, instead identifying scores >1.25 standard deviations below norms in

grammar and narrative language.

Table 3*: Analysis of Sensory Modalities in Grammar Intervention*

Study	Visual Techniques	Auditory-Verbal Techniques	Motor Techniques
Balthazar and Scott (2018)	Written stimuli for reference; Written production practice	Oral stimuli via computer application and clinician presentation	Writing production practice
Bredin-Oja and Fey (2014)	Specific stimuli selection derived from the child's attentional focus	Oral stimuli via clinician presentation	Not provided
Calder et al. (2018)	Visual cues using shapes, lines, and colors to represent targets; Written stimuli for reference	Oral instruction Oral stimuli via clinician presentation Oral cuing hierarchy provided	Participant movement of and pointing to visual cues
Curran and Owen Van Horne (2019)	Written text for reference Drawing to support production	Oral stimuli via text read aloud Oral models Oral cuing prompts	Drawing to support production
Eidsvåg Sunniva et al. (2019)	Visual cues to establish eye contact and attention	Auditory cues to establish eye contact and attention Oral models, elicitations, and recasts	Tactile cues to establish eye contact and attention
Feehan et al. (2015)	Not provided	Not provided	Not provided
Finestack (2018)	Not provided	Oral instruction via computer presentation Oral stimuli via computer presentation Oral cuing prompts	Not provided
Hsu and Bishop (2014)	Drawing stimuli representation	Oral instruction Oral stimuli via computer application	Not provided
Kulkarni et al. (2014)	Visual cues using shapes, lines, and colors to represent targets; Written stimuli for reference	Oral instruction Oral stimuli via clinician presentation	Writing production practice

Study	Visual Techniques	Auditory-Verbal Techniques	Motor Techniques
Meyers-Denman Christina and Plante (2016)	Visual cues to establish eye contact and attention	Auditory cues to establish eye contact and attention Oral models, elicitations, and recasts	Tactile cues to establish eye contact and attention
Owen Van Horne et al. (2018)	Not provided	Oral stimuli via text read aloud Oral models, elicitations, and recasts	Not provided
Owen Van Horne et al. (2017)	Visual representation of verbs Drawing to support production	Oral stimuli via text read aloud Oral models, elicitations, and recasts	Re-enactment of verbs Drawing to support production
Phillips (2014)	Written text for reference Drawing to support production	Oral stimuli via text read aloud Oral models Oral cuing prompts	Not provided
Plante et al. (2014)	Visual representation of verbs in semantic context	Oral models, elicitations, and recasts	Re-enactment of verbs for semantic context
Ramirez-Santana et al. (2018)	Written text for reference Drawing to support production	Oral stimuli via text read aloud Oral models, elicitations, and recasts Oral cuing prompts	Writing production practice Drawing to support production
Shahmahmood Toktam et al. (2018)	Written text for reference Visual representation of semantic context	Oral stimuli via text read aloud Oral models, elicitations, and recasts Oral cuing prompts	Not provided
Smith-Lock (2014)	Not provided	Oral models, elicitations, and recasts Oral cuing prompts	Not provided
Smith-Lock et al. (2015)	Not provided	Oral models, elicitations, and recasts Oral cuing prompts	Not provided
To Carol et al. (2015)	Written text for reference Visual representation of semantic context	Oral instruction Oral stimuli via clinician presentation	Writing production practice

Study	Visual Techniques	Auditory-Verbal Techniques	Motor Techniques
Zwitserlood et al. (2015)	Visual cues using shapes and colored objects to represent targets Written stimuli for reference	Oral instruction Oral stimuli via clinician presentation Oral cuing prompts	Movement of coded objects to represent target syntax

Table *4. Summary of Participant Characteristics*

Participant	P2	P3	P4	P5
Age	5;5	4;7	6;9	4;8
Gender	Male	Male	Female	Male
Ethnicity	Caucasian	African-American	Asian	Latino
Global Language Severity	Mild	Severe	Within Normal Limits	Within Normal Limits
Receptive Language Severity	Within Normal Limits	Moderate	Within Normal Limits	Within Normal Limits
Expressive Language Severity	Moderate	Severe	Mild	Mild
Grammar Severity	Mild	Severe	Severe	Moderate
Co-morbid Disorders and Severity	Moderate Articulation Delay (Childhood Apraxia of Speech)	Severe Articulation Delay; Moderate Attention Deficit Disorder	Severe Articulation Delay (Repaired Cleft Palate); Moderate Attention Deficit Disorder	Severe Articulation Delay
Behavioral Regulation Severity	Above Criterion	Below Criterion	Above Criterion	Above Criterion
Metacognition Severity	Above Criterion	Below Criterion	Above Criterion	Below Criterion
Global Executive Function Severity	Above Criterion	Below Criterion	Above Criterion	Below Criterion
Observed Activity Level	Appropriate	High	High	Moderate

Table 5. *Participant Language Characteristics*

Participant	Total Language Score	Receptive Language Score	Expressive Language Score	Total Grammar Score (Criterion)	Third Person Singular (Criterion)	Past Tense (Criterion)	Be (Criterion)	Do (Criterion)
P2	82	102	76	59.8 (66)	56 (89)	12 (73)	89 (79)	82 (56)
P3	69	75	59	10.5 (59)	0 (76)	0 (73)	42 (93)	0 (46)
P4	93	100	83	28 (81)	0 (91)	35 (87)	33 (90)	45 (76)
P5	88	101	83	25 (59)	10 (76)	0 (73)	33 (93)	58 (46)

Note. Language Scores are based on a mean of 100, standard deviation of 15. Specific grammar scores reflect performance on the Test of Early Grammatical Impairment (Rice & Wexler, 2001), with criteria for each participant's age shown in parentheses.

Table 6. *Participant Executive Function Characteristics*

Participant	P2	P3	P4	P5
Inhibit	69	**62**	80	76
Shift	70	**50**	**64**	**40**
Emotional Control	71	**38**	**63**	71
Behavioral Regulation Index	73	**50**	72	67
Initiate	**55**	**42**	**59**	**46**
Working Memory	68	**60**	81	**53**
Plan/Organize	72	**41**	72	**<37**
Organization of Materials	69	**56**	70	**53**
Monitor	66	**51**	**62**	**47**
Metacognition Index	68	**50**	73	**43**
Global Executive Composite	72	**50**	75	**53**

Note: Subtest and composite T-scores reported from the Behavior Rating Inventory of Executive Function (Gioia, Isquith, Guy, & Kenworthy, 2015). Scores below expectations for the participant's age are marked with **bold font**.

Table *7. Test of Early Grammatical Impairment Screening Information*

Age	Criterion Score	Sensitivity	Specificity
4;0 – 4;5	63	0.90	0.80
4;6 – 4;11	65	0.94	0.80
5;0 – 5;5	78	0.86	0.80
5;6 – 5;11	80	0.94	0.80
6;0 – 6;5	85	0.92	0.80
6;6 – 6;11	88	0.90	0.80

Table 8. *Average Production Accuracy in Acquisition Activities Across Phases and Participants*

		Motor Production Percentage Mean (Standard Deviation)	Visual Production Percentage Mean (Standard Deviation)	Control Production Percentage Mean (Standard Deviation)
	Baseline	63 (18.0)	43 (13.4)	51 (8.4)
P2	Intervention	85 (11.8)	76 (20.0)	40 (12.5)
	Maintenance	94 (5.5)	88 (8.4)	52 (13.0)
	Baseline	8 (8.7)	1 (2.2)	17 (14.0)
P3	Intervention	50 (22.6)	53 (32.4)	42 (18.8)
	Maintenance	42 (18.8)	15 (27.7)	54 (29.7)
	Baseline	21 (11.5)	18 (18.8)	77 (26.3)
P4	Intervention	73 (10.7)	69 (8.2)	4 (10.6)
	Maintenance	33 (22.9)	68 (28.4)	0 (0)
	Baseline	10 (8.2)	8 (11.7)	22 (16.1)
P5	Intervention	55 (19.6)	57 (27.2)	5 (9.5)
	Maintenance	48 (11.8)	55 (7.7)	6 (5.2)

Table 9. *Average Production Accuracy in Retention Probes Across Phases and Participants*

		Motor Production Mean (Standard Deviation)	Visual Production Mean (Standard Deviation)	Control Production Mean (Standard Deviation)
P2	Baseline	40 (15.8)	44 (15.2)	28 (8.4)
	Intervention	72 (25.3)	60 (18.5)	-
	Maintenance	76 (26.1)	52 (26.8)	-
	Generalization	94 (8.9)	66 (8.9)	36 (8.9)
P3	Baseline	0 (0)	0 (0)	6 (8.9)
	Intervention	10 (18.5)	0 (0)	-
	Maintenance	32 (26.8)	0 (0)	-
	Generalization	0 (0)	0 (0)	8 (8.4)
P4	Baseline	45 (25.9)	35 (37.3)	76 (13.7)
	Intervention	40 (18.5)	30 (32.1)	-
	Maintenance	44 (30.0)	36 (21.9)	-
	Generalization	44 (11.4)	18 (20.5)	58 (13.0)
P5	Baseline	7 (8.2)	2 (4.1)	22 (9.8)
	Intervention	13 (10.4)	23 (22.5)	-
	Maintenance	40 (0)	64 (16.7)	-
	Generalization	42 (13.0)	48 (8.4)	12 (8.4)

Table 10. *Functional Use of Target Structures in Natural Language*

Participant	Sample Time	Motor Targets		Visual Targets		Control Targets	
		Percent Correct	Number of Attempts	Percent Correct	Number of Attempts	Percent Correct	Number of Attempts
P2	Initial	100%	2	71%	7	100%	2
	Final	100%	3	100%	5	100%	12
P3	Initial	0%	4	0%	7	70%	10
	Final	50%	2	60%	5	53%	17
P4	Initial	100%	1	24%	17	100%	1
	Final	100%	2	32%	22	100%	1
P5	Initial	0%[a]	2[a]	0%[b]	0	0%[b]	0
	Final	50%[a]	2[a]	100%	2	50%	2

[a] P5's motor target was *do* question inversion. No attempts were made at this target within either of his natural language samples. The data reported is on general inverted questions. [b] No attempts were made at this target, so accuracy level is reported as 0% by default.

Table 11. *Generalized Language Improvement from Language Sample Analysis*

Participant (SUGAR Norm Group)	Time	TNW	*z-* score	MLU$_S$	*z-* score	WPS	*z-* score	CPS	*z-* score
P2	Initial	276	-0.387	6.28	-0.28	5.80	-1.26	**1.05**	**-1.8**
(5;0-5;11)	Final	279	-0.339	6.28	-0.28	5.85	-1.22	**1.23**	**-0.5**
P3	Initial	172	-1.774	3.68	-1.89	**4.30**	**-2.13**	0.98	-2.1
(4;6-4;11)	Final	223	-0.926	4.96	-0.92	**6.97**	**-0.02**	1.21	0.0
P4 (6;0-6;11)*	Initial	238	-1.376	4.98	-1.64	*6.03*	*-1.42*	1.08	-2.0
(7;0-7;11)*	Final	267	-1.798	5.98	-1.67	*5.45*	*-2.82*	1.08	-2.2
P5	Initial	**143**	**-2.257**	**2.96**	**-2.44**	4.53	-1.95	1.00	-1.9
(4;6-4;11)	Final	**322**	**0.72**	**6.62**	**0.33**	6.44	-0.44	1.12	-0.8

Note. Positive changes of more than a standard deviation are designated in **bold font**. Negative changes of more than a standard deviation are designated in *italic font*.

Table 12. *Tau-U and p Values by Data and Intervention Types*

	Motor	Visual	Control
Retention	0.4501; $p = 0.0029$	0.1469; $p = 0.0351$	-0.0485; $p = 0.7955$
Acquisition	**0.6822; $p = 0$**	0.5939; $p = 0.0010$	-0.4208; $p = 0.0051$

Note. Bold type indicates a clear effect.

Table 13. *Implementation Fidelity Session Numbers by Participant and Phase*

Participant	Baseline	Intervention	Maintenance
2	1, 2	1, 2, 5	4, 5
3	1, 3	2, 3, 4	2, 3
4	2, 5	2, 7, 8	2, 4
5	4, 5	2, 3, 7	1, 4

Table 14. *Implementation Fidelity by Participant and Phase*

Participant	Baseline	Intervention	Maintenance	Participant Total
2	85%	92%	85%	88%
3	95%	100%	90%	96%
4	80%	74%	65%	73%
5	90%	93%	65%	84%
Grand Total	**88%**	**90%**	**76%**	**85%**

Table 15. *Social Validity Results*

Statement	Parent Average Score	Graduate Student Average Score
My child/client benefitted from the grammar intervention.	4.8	4.0
My child/client has used the hand movements they learned to add grammar markers in their speech or writing.	3.0	3.7
My child/client has referenced the color and shapes they learned to add grammar markers in their speech or writing.	3.6	3.7
My child's/client's grammar has significantly improved over the course of treatment.	4.4	3.3
I would recommend this treatment program for other children with grammar difficulties	4.8	NA
I would like my student to continue with this intervention program.	4.5	NA
I learned appropriate procedures for treatment of grammar difficulties within this study.	NA	4.7
I feel confident in my ability to provide appropriate intervention for children with grammar difficulties.	NA	4.3
I believe it was worth my time and effort to learn these intervention strategies.	NA	5.0
I will use these techniques for other clients with similar grammar difficulties.	NA	4.7

Note. Scores from a 5-item Likert scale, with 1 = Strongly Disagree and 5 = Strongly Agree.

NA = not applicable

FIGURES
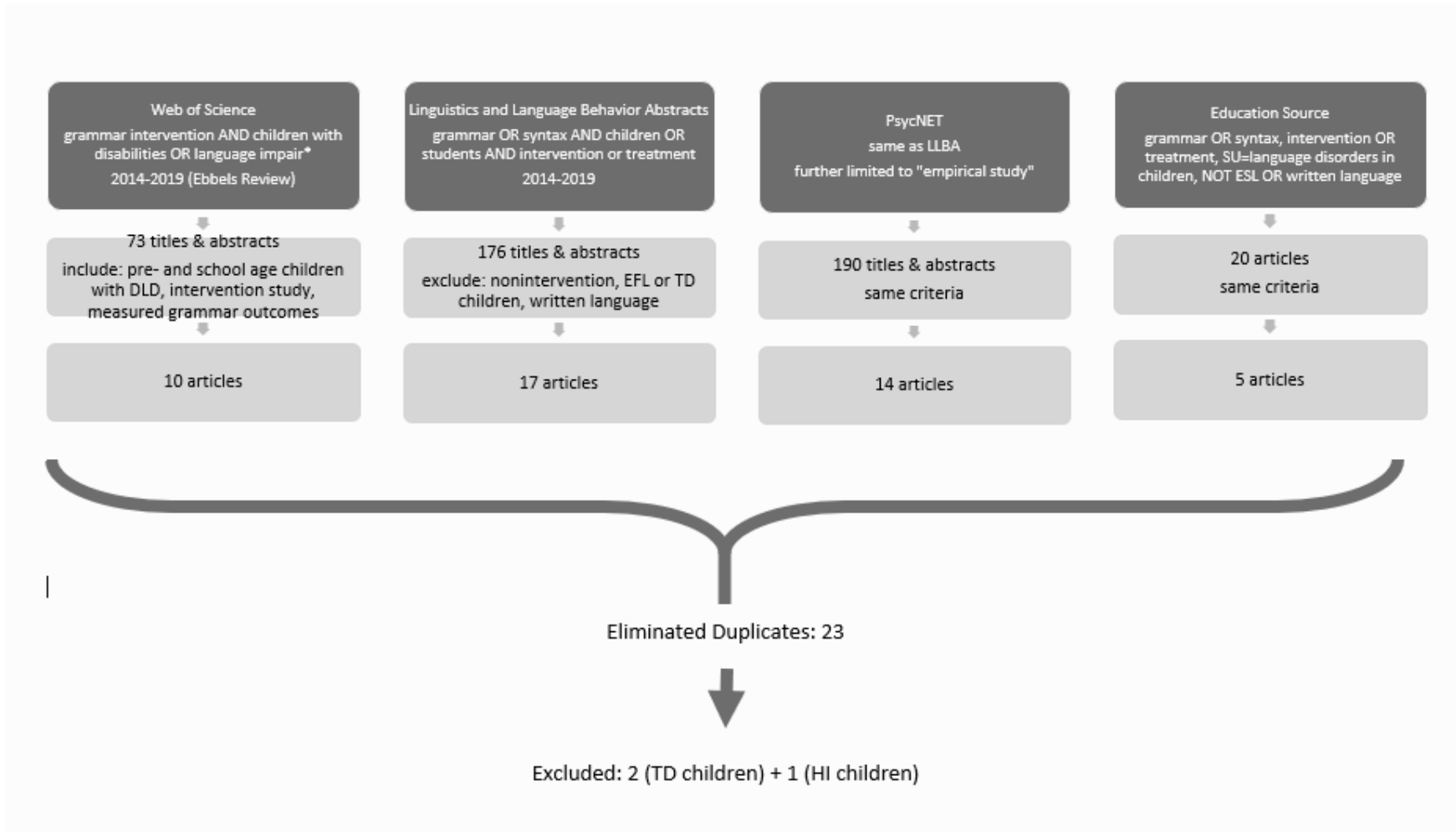
Figure 1. Literature Search Summary
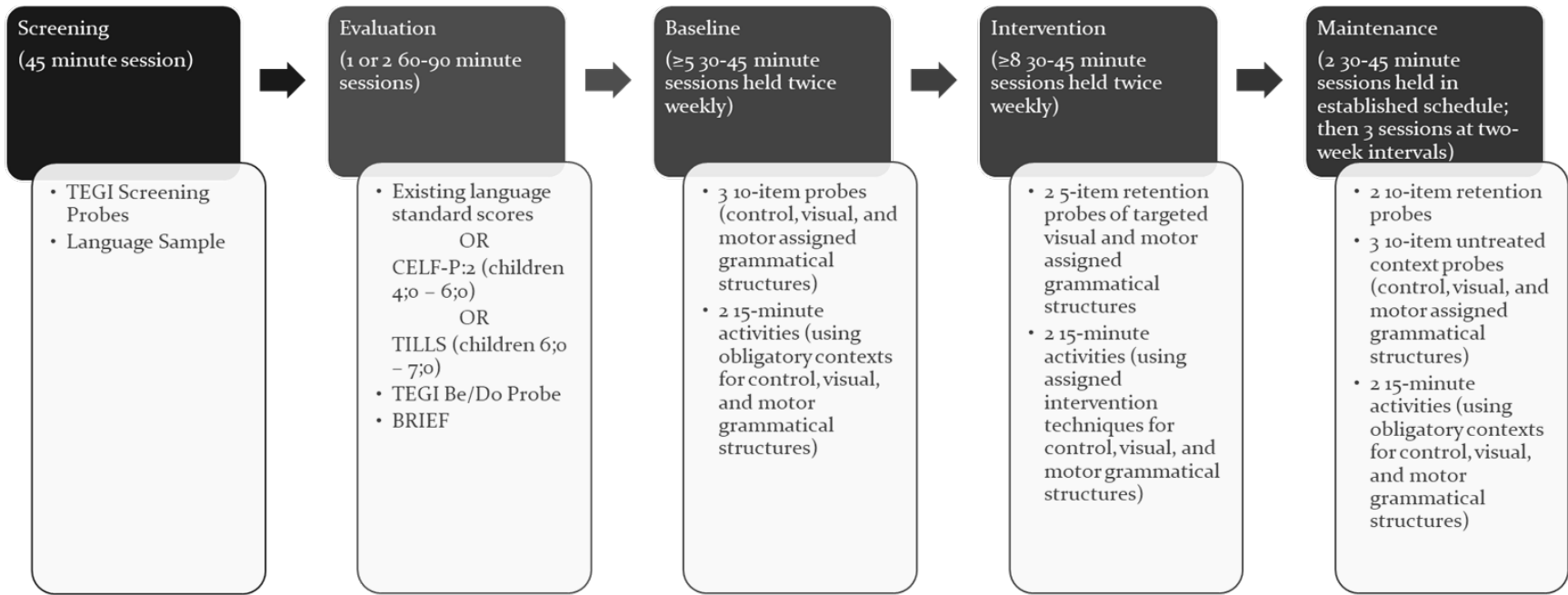
Figure 2. Sequence of Study Procedures

Past Tense -ed

Flat hand moves from
palm-up waist level to
palm-down over
shoulder

Plural -s

S-hand moves from chest
level front of body to the
right at arm length

Pronoun _he_

E-hand moves from
forehead level forward
and down to arm length
in the direction of the
referent or referent's
picture
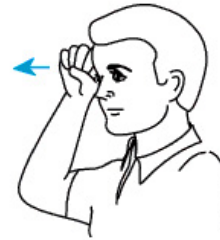
Illustrations provided by Signing Exact English web dictionary, https://www.signingexactenglish.com/see.asp

Figure 3. Examples of motor techniques
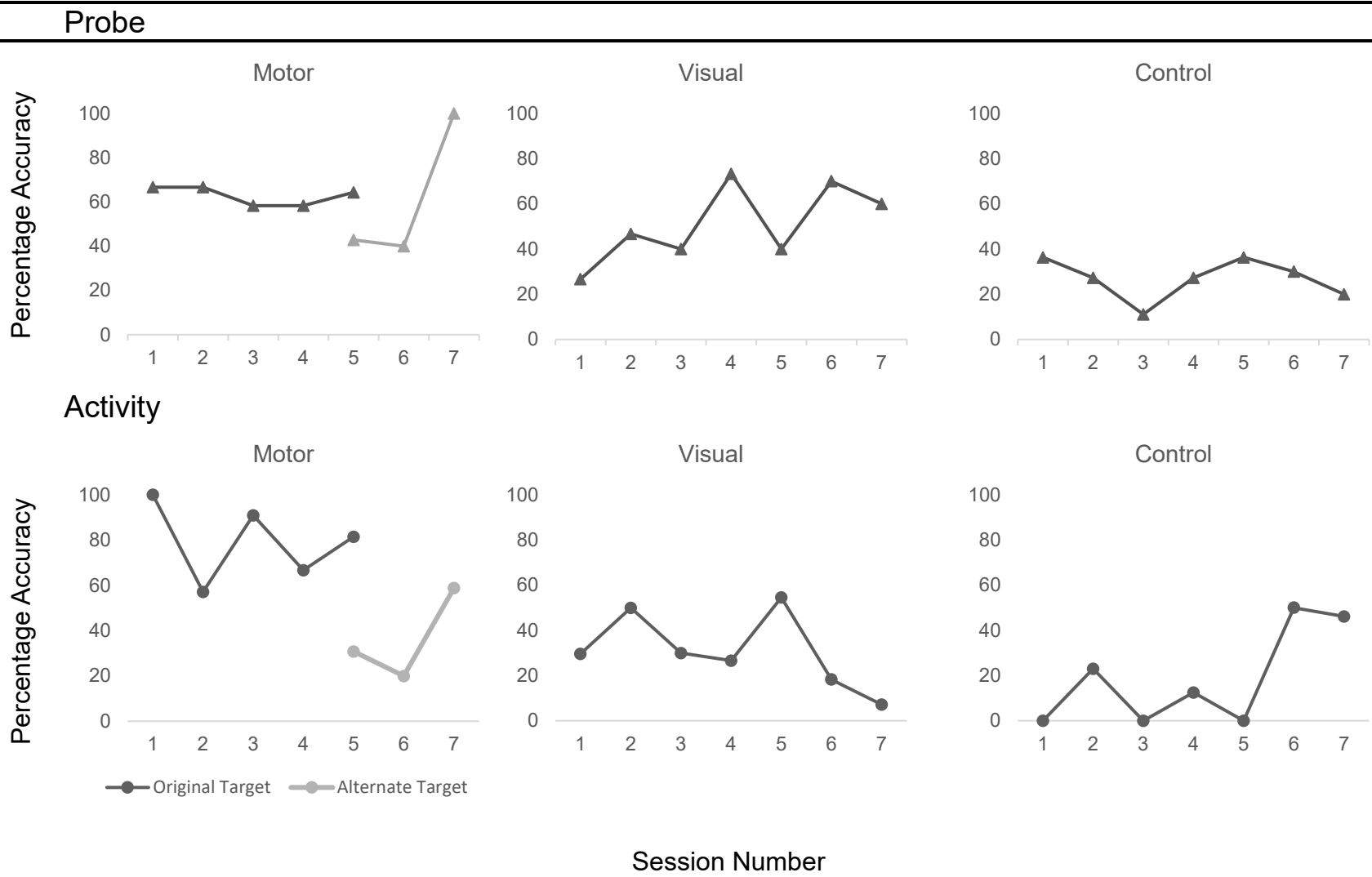
Figure 4. P1 Baseline Data
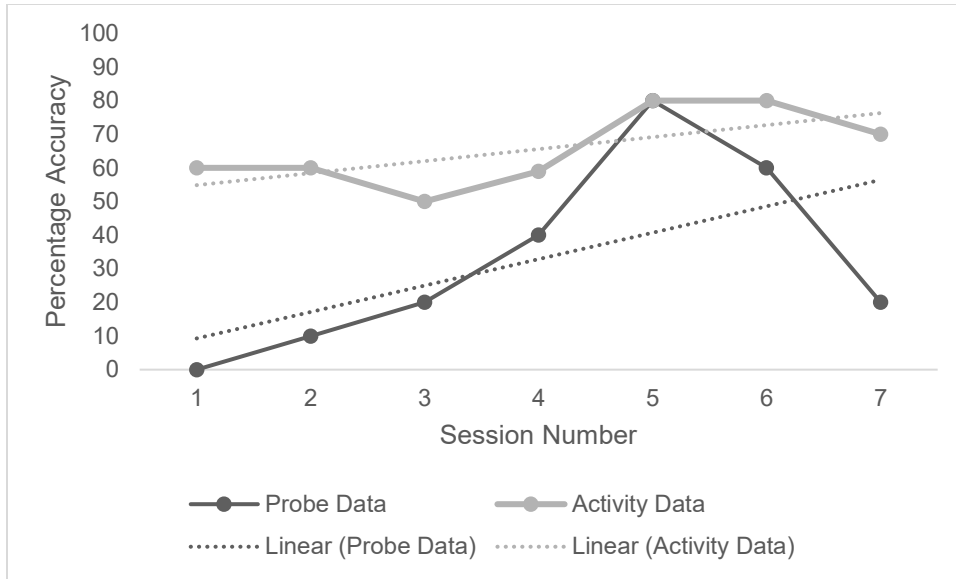
Figure 5. P2 Baseline Motor Data (Target Withdrawn)
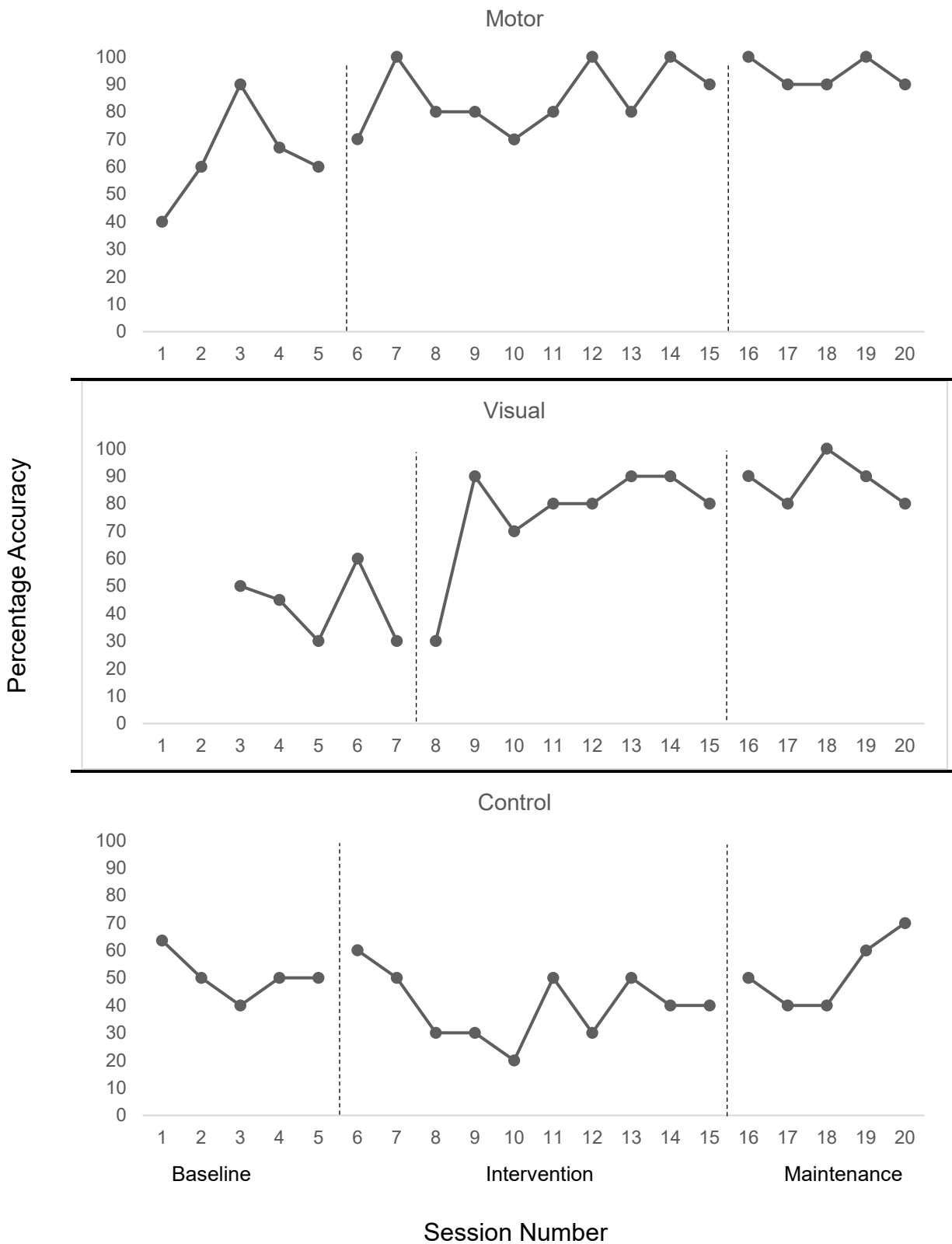
Figure 6. Acquisition Activity Results for P2
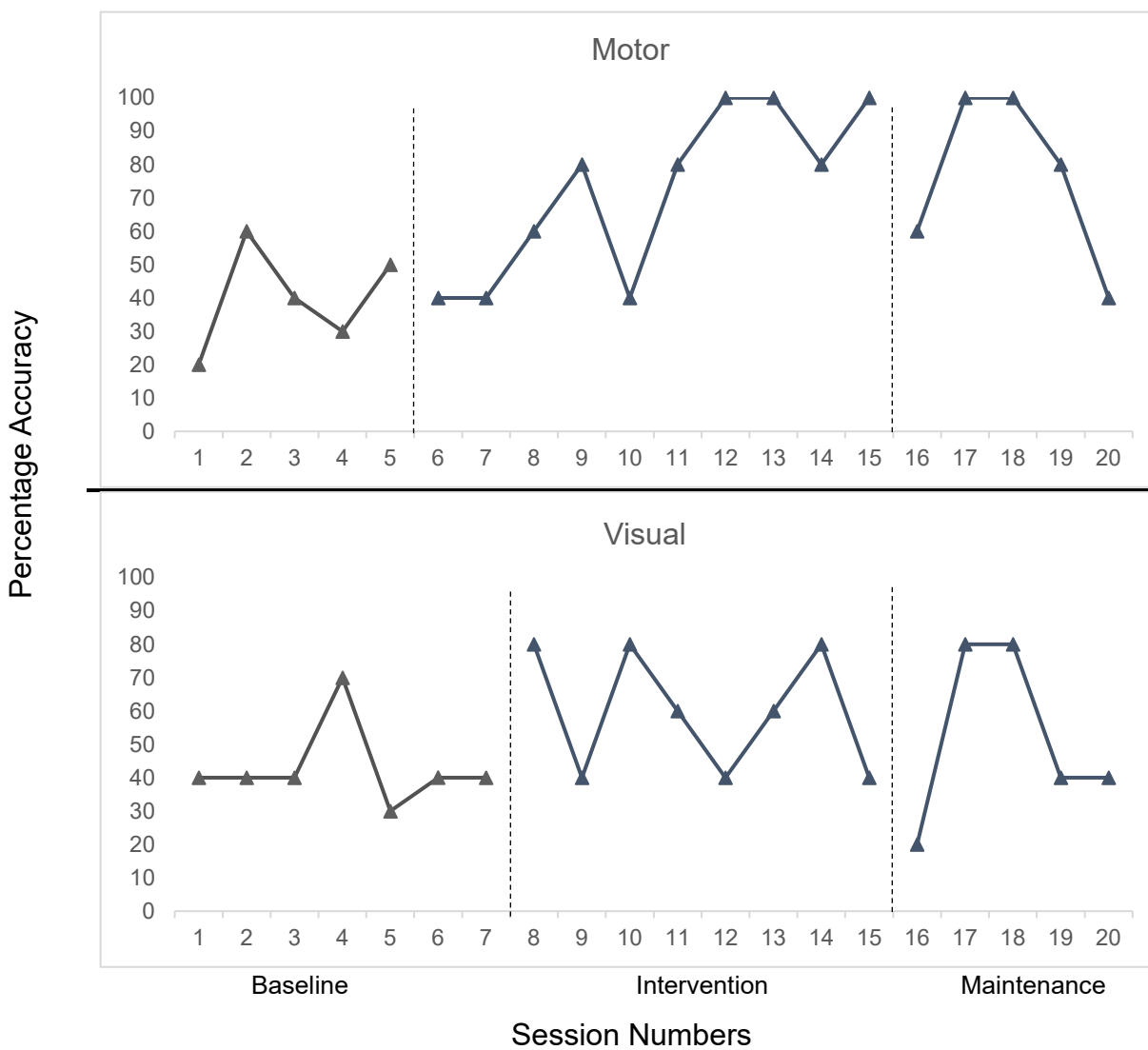
Figure 7. Retention Data for P2
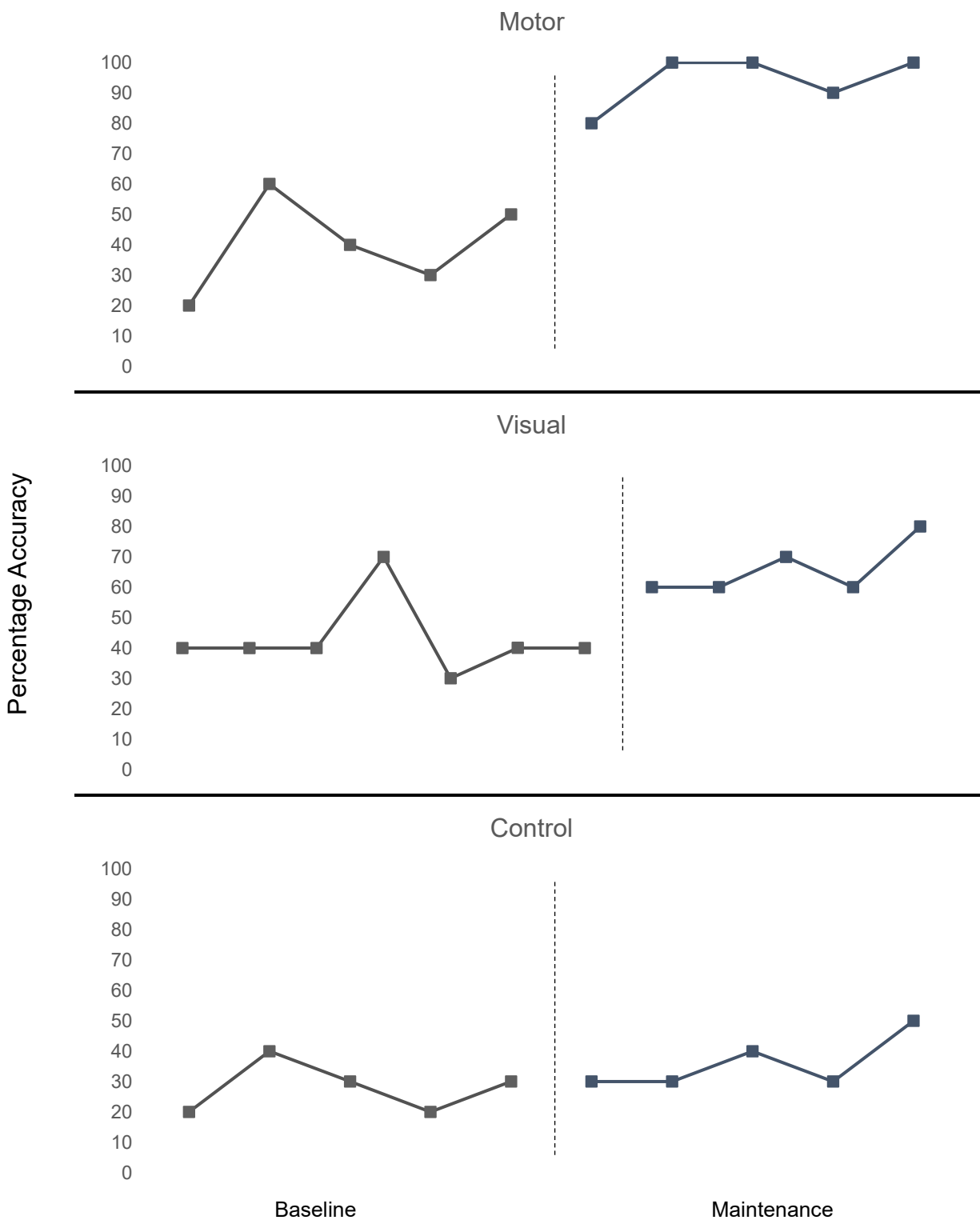
Figure 8. Generalization Data for P2
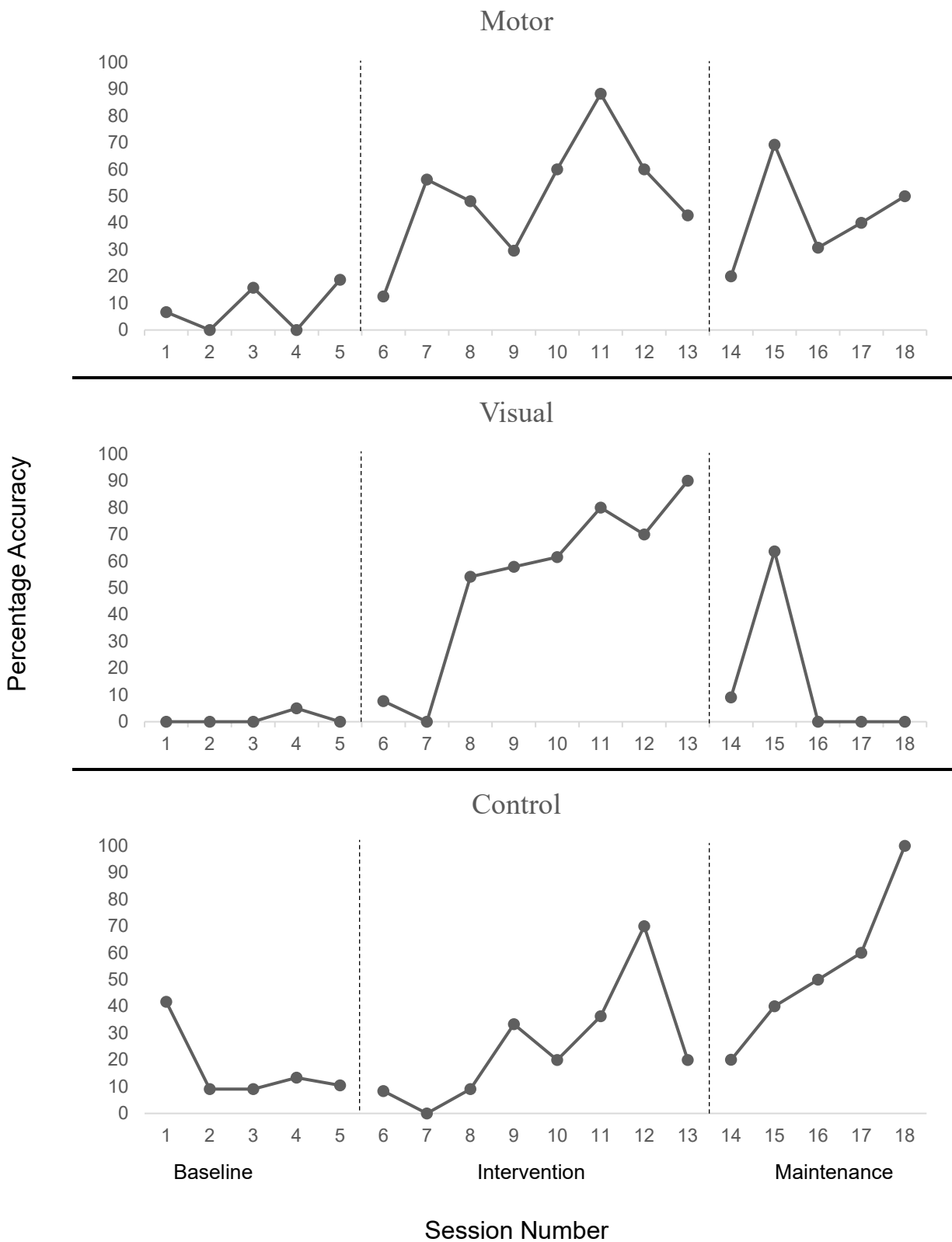
Figure 9. *Acquisition Activity Results for P3*
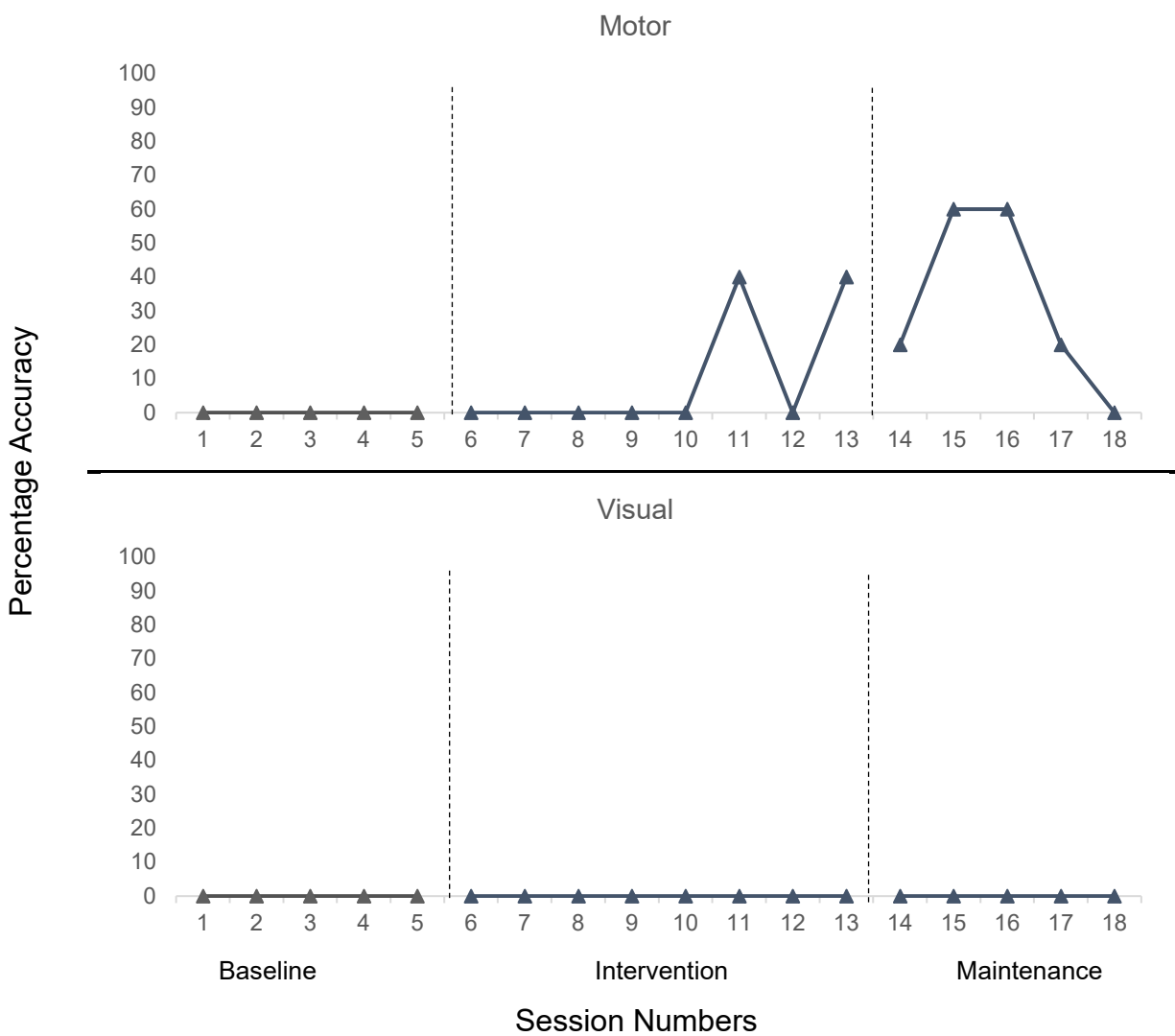
Figure 10. Retention Data for P3
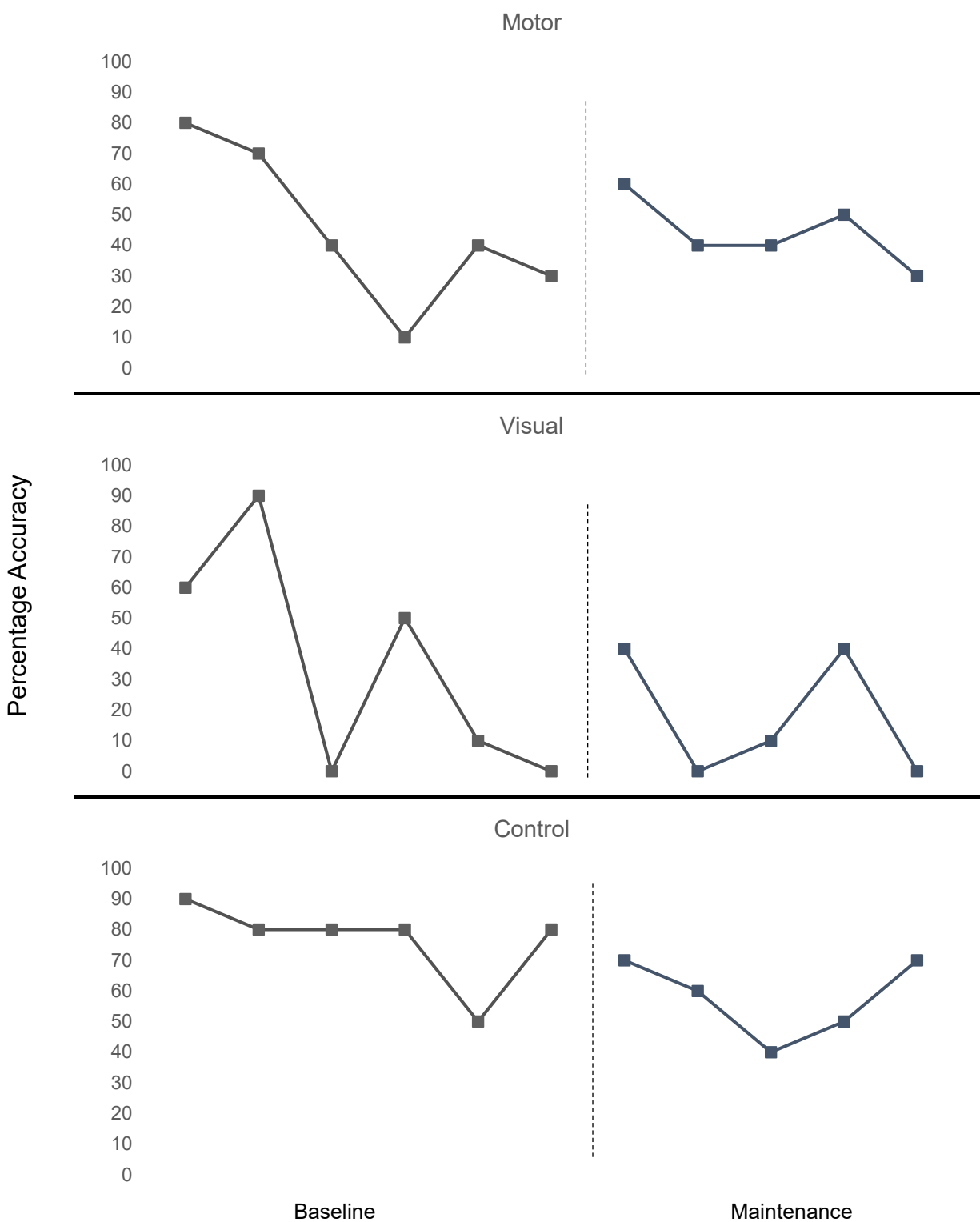
Figure 11. Generalization Data for P3
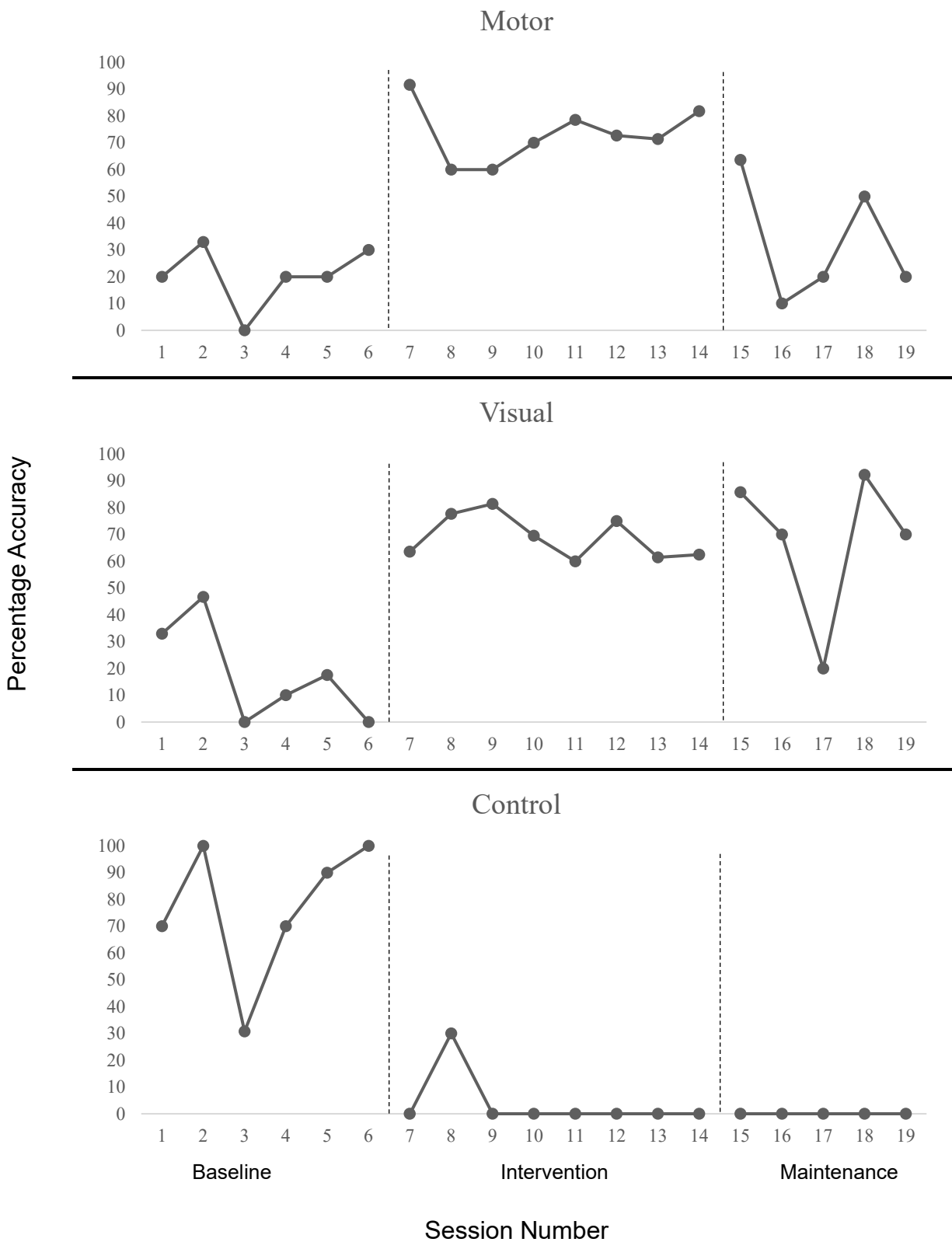
Figure 12. Acquisition Activity Data for P4
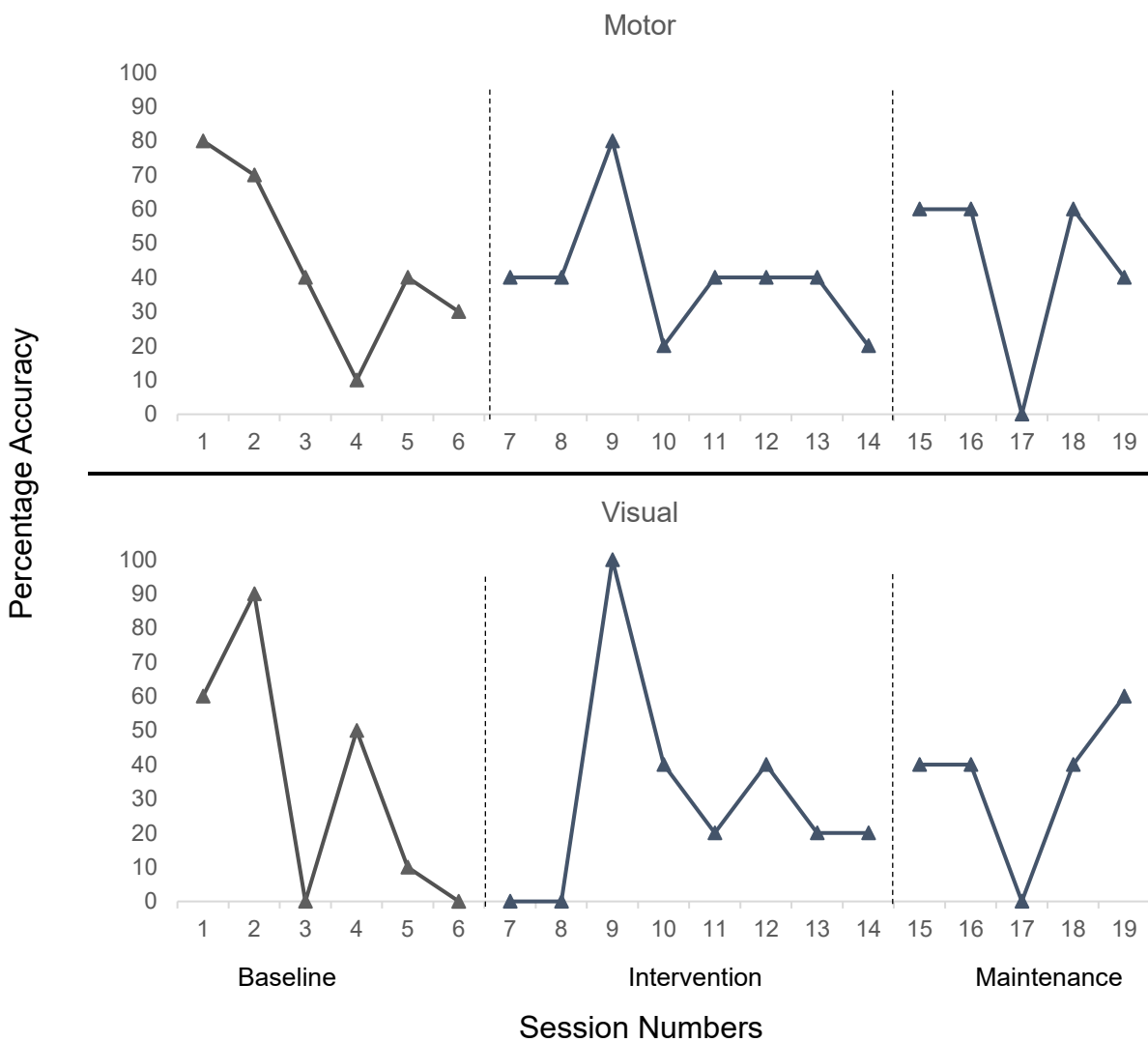
Figure 13. *Retention Data for P4*
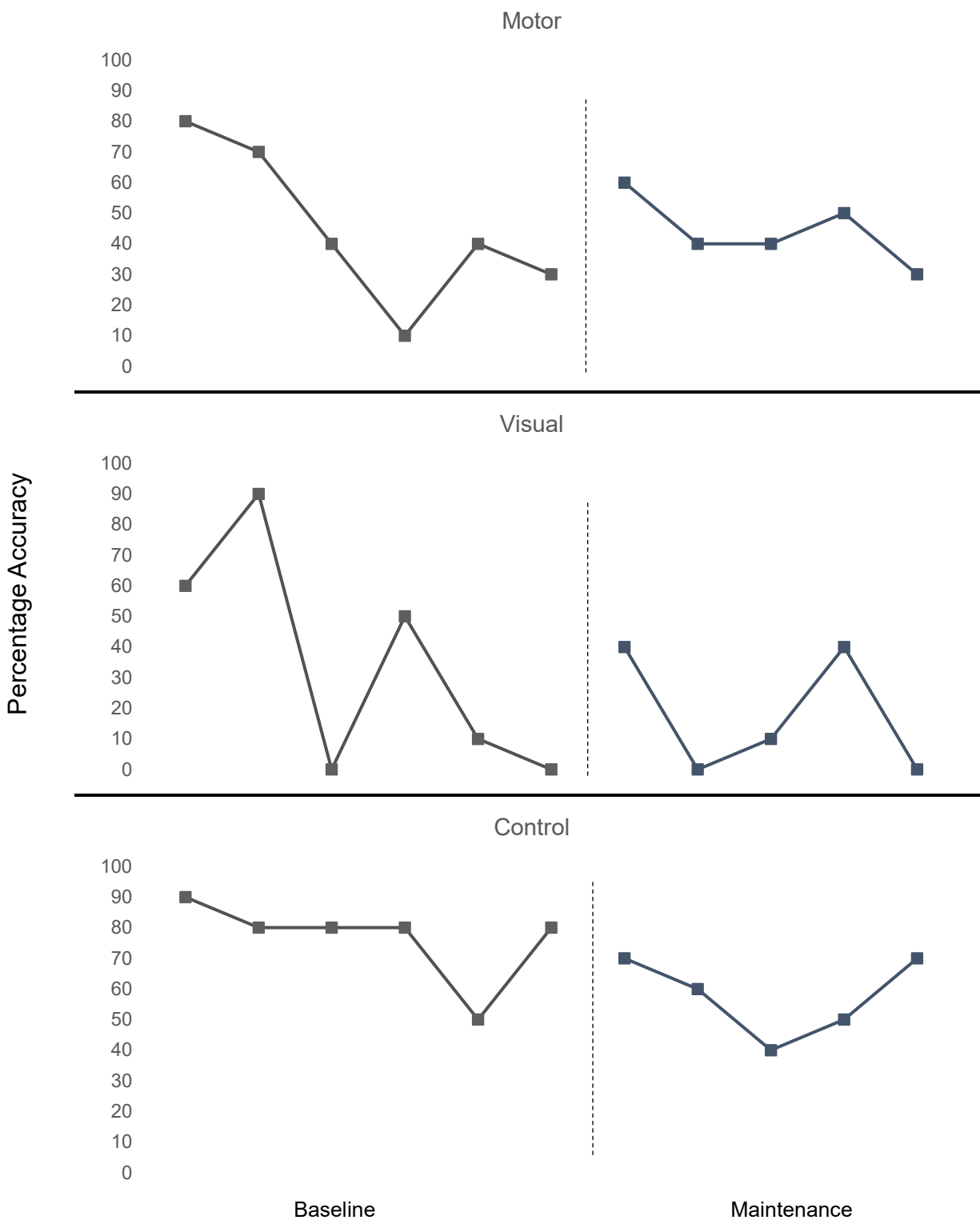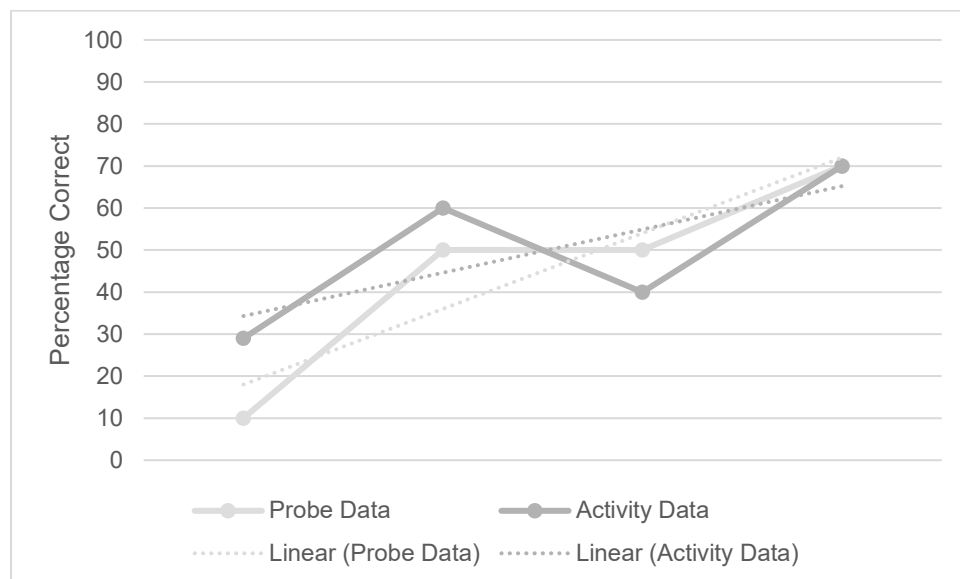
Figure 14. Generalization Data for P4

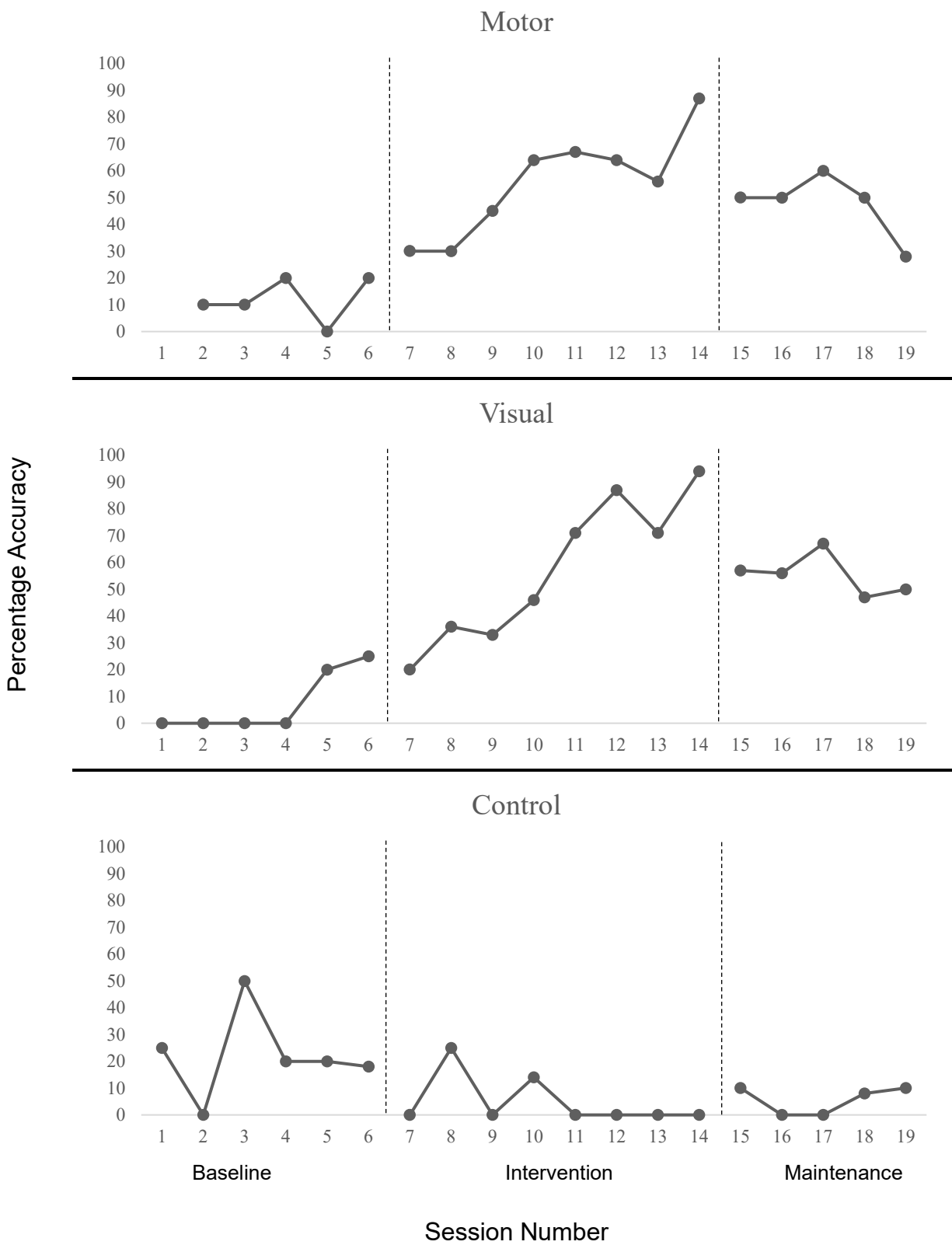*Figure 15.* P5 Baseline Motor Data (Target Withdrawn)
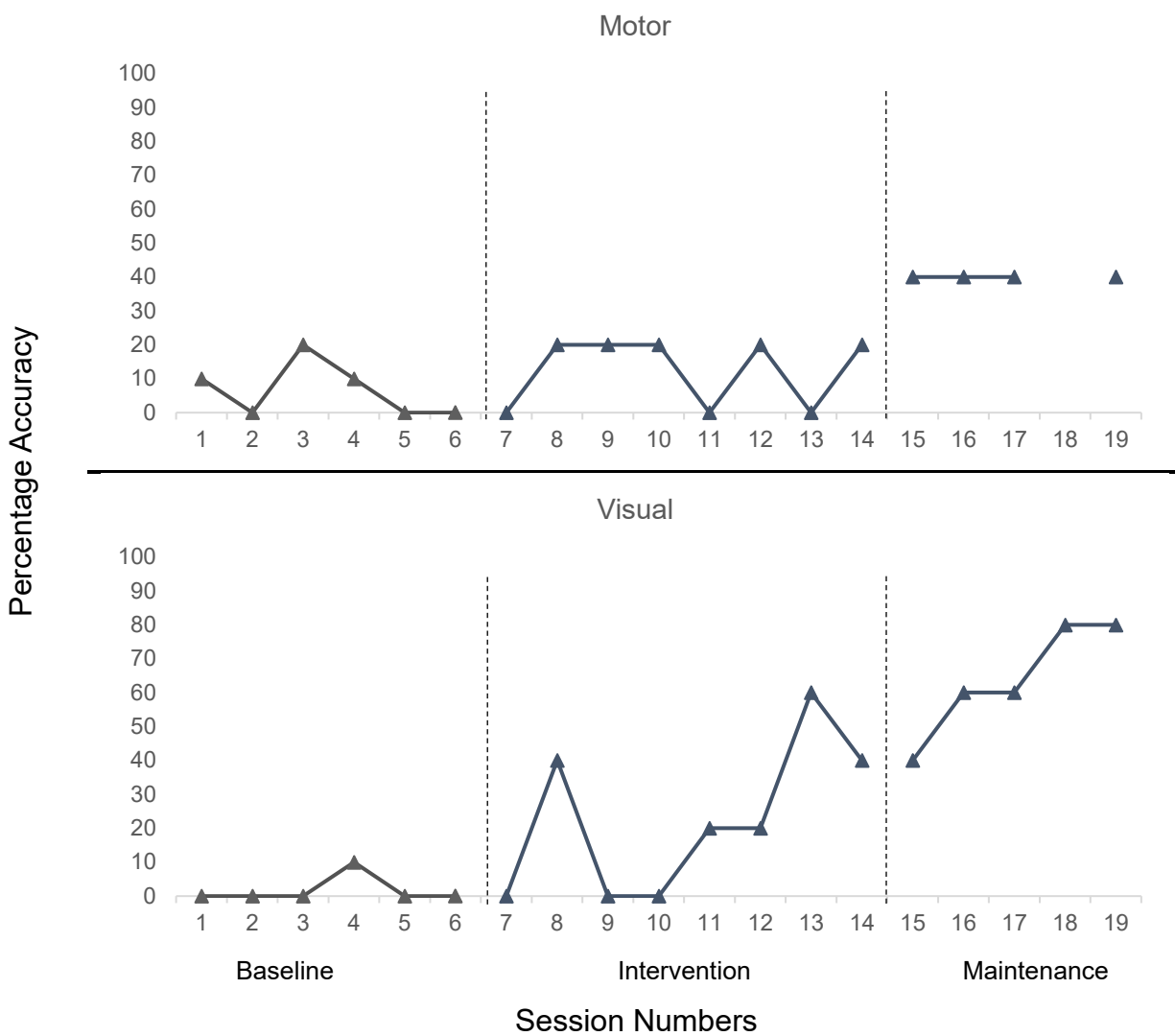
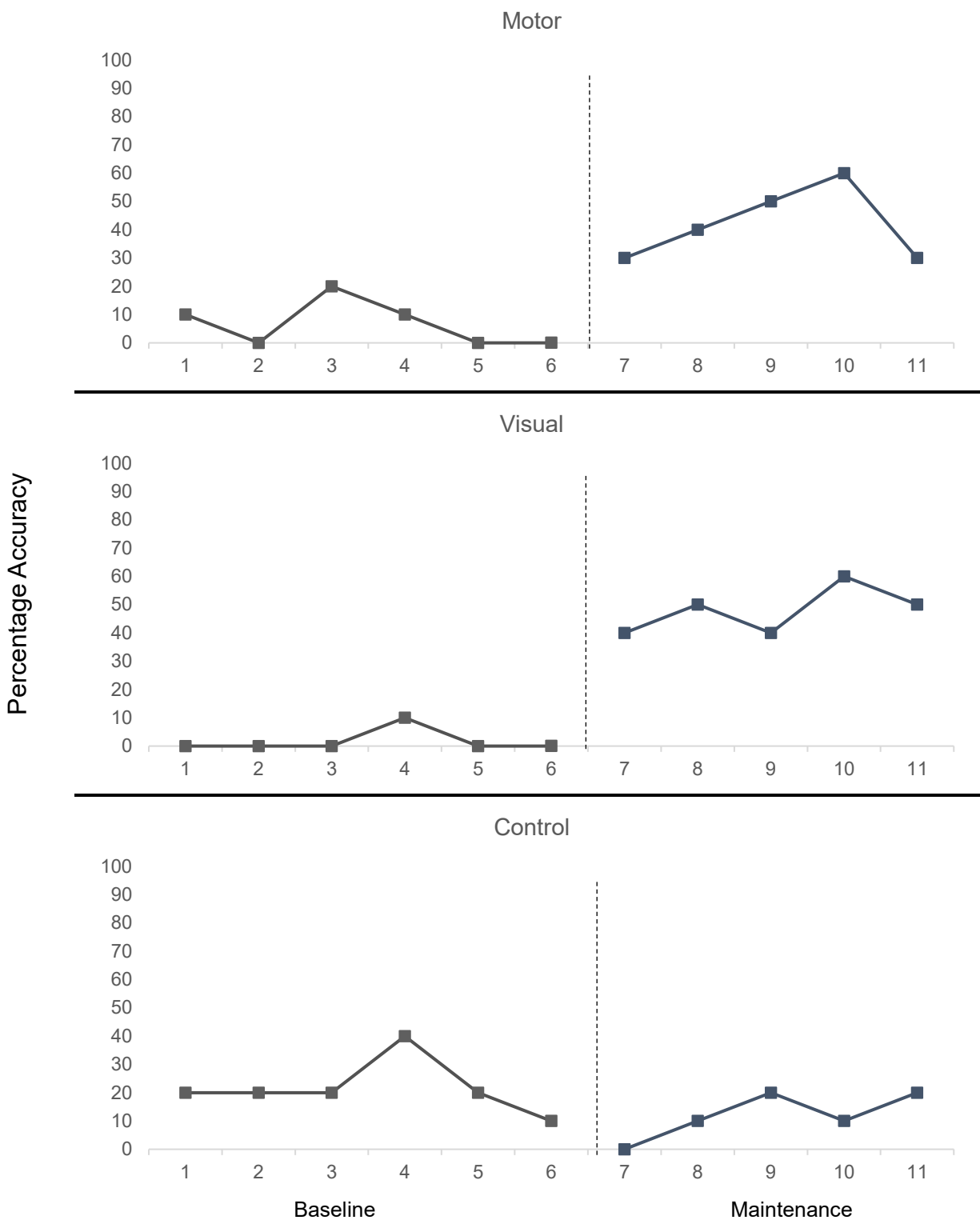*Figure 16.* Acquisition Activity Data for P5

Figure 17. Retention Data for P5

Figure 18. Generalization Data for P5

APPENDIX A

Implementation Fidelity Checklists

Participant: Date:		Not Observed NA	Completed
Clinician completes three 10-item probes.			
Baseline Implementation			**Observer Initials:**
One of three therapy activities is chosen: reading a story, free play, or craft activities. (Content)			
Clinician engages in therapy activity with student with DLD for 15 minutes. (Content)			
Production procedures	Clinician elicits production of grammatical structure 1, e.g. "Let's talk about the pictures in this story" or "Let's talk about what we do."		
	Clinician provides verbal recasts and opportunities for language production.		
Feedback procedures	Clinician thanks student for telling them about the therapy activity.		
One of three therapy activities is chosen: reading a story, free play, or craft activities. (Content)			
Clinician engages in therapy activity with student with DLD for 15 minutes. (Content)			
Production procedures	Clinician elicits production of grammatical structure 2, through an event retell, e.g. "Tell me what happened".		
	Clinician provides verbal recasts and opportunities for language production.		
Feedback procedures	Clinician thanks student for telling them about the therapy activity.		

		Not Observed NA	Completed
Participant: **Date:** **Observer Initials:**			
Clinician completes 2 5-item probes.			
First Grammar Intervention/Maintenance Implementation Indicate type of intervention: □ Visual □ Motor			
One of three therapy activities is chosen: reading a story, free play, or creating a craft. (Content)			
Clinician explains use of grammatical structure.			
Clinician demonstrates and prompts student to produce grammatical structure in a demonstration sentence.			
Clinician's method of production corresponds exclusively to targeted intervention technique, e.g. verbal and visual, verbal and motor. (Content)			
Production procedures	Clinician reminds student to use grammatical structure, (e.g. "While we play, remember to use all the parts of your words.")		
	Clinician elicits production of target grammatical morphemes throughout chosen therapy activity.		
	Clinician models production for target grammatical morphemes in appropriate intervention mode throughout chosen therapy activity.		
	Clinician responds to omission of grammatical structure by recasting with correct production, i.e. provides model.		
Feedback procedures	Clinician responds to inclusion of grammatical structure with specific praise and expansion, reinforcing the grammatical structure		
	Clinician prompts student to repeat utterances with grammatical structure by giving a verbal cue, e.g. "Remember to use all the parts of your words," or verbally starting the correct production, i.e. cloze procedure.		
	Clinician thanks student for using grammatical structure while they completed therapy activity, e.g. "Thank you for using good word endings while we made our craft today."		
At least 10 opportunities to produce target grammatical morphemes are provided within a 15-minute session. (Content)			

| Second Grammar Intervention/Maintenance Implementation Indicate type of intervention: □ Visual □ Motor			
One of three therapy activities is chosen: reading a story, free play, or creating a craft. (Content)			
Clinician explains use of grammatical structure.			
Clinician demonstrates and prompts student to produce grammatical structure in a demonstration sentence.			
Clinician's method of production corresponds exclusively to targeted intervention technique, e.g. verbal and visual, verbal and motor. (Content)			
Production procedures	Clinician reminds student to use grammatical structure, (e.g. "While we play, remember to use all the parts of your words.")		
	Clinician elicits production of target grammatical morphemes throughout chosen therapy activity.		
	Clinician models production for target grammatical morphemes in appropriate intervention mode throughout chosen therapy activity.		
	Clinician responds to omission of grammatical structure by recasting with correct production, i.e. provides model.		
Feedback procedures	Clinician responds to inclusion of grammatical structure with specific praise and expansion, reinforcing the grammatical structure		
	Clinician prompts student to repeat utterances with grammatical structure by giving a verbal cue, e.g. "Remember to use all the parts of your words," or verbally starting the correct production, i.e. cloze procedure.		
	Clinician thanks student for using grammatical structure while they completed therapy activity, e.g. "Thank you for using good word endings while we made our craft today."		
At least 10 opportunities to produce target grammatical morphemes are provided within a 15-minute session. (Content)			

Participant: Date:	Not Observed NA	Completed
Clinician completes two 10-item probes.		
Maintenance Implementation		**Observer Initials:**
One of three therapy activities is chosen: reading a story, free play, or craft activities. (Content)		
Clinician engages in therapy activity with student with DLD for 15 minutes. (Content)		
Production procedures · Clinician elicits production of grammatical structure 1, e.g. "Let's talk about the pictures in this story" or "Let's talk about what we do."		
· Clinician provides verbal recasts and opportunities for language production.		
Feedback procedures · Clinician thanks student for telling them about the therapy activity.		
One of three therapy activities is chosen: reading a story, free play, or craft activities. (Content)		
Clinician engages in therapy activity with student with DLD for 15 minutes. (Content)		
Production procedures · Clinician elicits production of grammatical structure 2, through an event retell, e.g. "Tell me what happened".		
· Clinician provides verbal recasts and opportunities for language production.		
Feedback procedures · Clinician thanks student for telling them about the therapy activity.		
Final Maintenance Session		
Clinician completes three 10-item probes		
Clinician elicits a 50-utterance language sample		

SHAPE CODING™ colours

Noun / Pronouns   (boy, table, I)

Det / Possessive pronouns   (the, a, my)

Verb   (push, melt)

Adjective   (hard, sad)

Preposition   (in, through)

Adverb   (quickly, carefully)

Coordinating conjunction   (and, but, or)

Subordinating conjunction   (because, if)

SHAPE CODING™ shapes
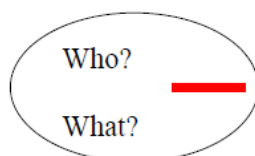
NP: Subject
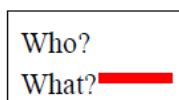
NP: Object
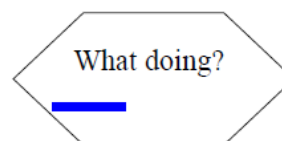
Verb Phrase
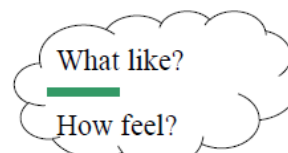
Adjective Phrase

Subject verb agreement

Verb tenses

APPENDIX C

Social Validity for Clinicians

Please indicate your agreement with the following statements, by circling the appropriate response:

1. **My client benefitted from the grammar intervention they received.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

2. **My client has used the hand movements they learned to add grammar markers in their speech or writing.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

3. **My student has referenced the color and shapes they learned to add grammar markers in their speech or writing.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

4. **My client's grammar has significantly improved over the course of treatment.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

5. **I learned appropriate procedures for treatment of grammar difficulties within this study.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

6. **I feel confident in my ability to provide appropriate intervention for children with grammar difficulties.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

7. **I believe it was worth my time and effort to learn these intervention techniques.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

8. **I will use these techniques for other clients with similar grammar difficulties.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

9. **I prefer the following intervention modality:**

Visual (Shapes and Colors)   Tactile-Kinesthetic (Gestures)

To help us in further investigations, please provide more information:

10. **Why did you prefer the modality circled above?**

11. **What other comments on your participation in this study do you have?**

Social Validity for Parents

Please indicate your agreement with the following statements, by circling the appropriate response:

1. **My child benefitted from the grammar intervention they received.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

2. **My child has used the hand movements they learned to add grammar markers in their speech or writing.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

3. **My student has referenced the color and shapes they learned to add grammar markers in their speech or writing.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

4. **My child's grammar has significantly improved over the course of treatment.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

5. **I would recommend this treatment program for other children with grammar difficulties.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

6. **I would like my student to continue with this intervention program.**

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

7. **I prefer the following intervention modality:**

Visual (Shapes and Colors)   Tactile-Kinesthetic (Gestures)

To help us in further investigations, please provide more information:

8. **Why did you prefer the modality circled above?**

9. **What was the most significant benefit to your child from this intervention?**

10. **Would you like the opportunity to learn more about this intervention program for home use?**

11. **What other comments on your child's participation in this study do you have?**