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Visual Support in Intervention for Preschoolers With Specific Language Impairment

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This study was conducted as a follow-up analysis to two prior studies using existing data gathered in those original studies. In the current study, we focus on those preschoolers who received one of two interventions that varied in terms of the level of visual supports for grammatical elements ($n = 22$ of the original 34 participants). Utilizing random selection for intervention, our study examined potential session-to-session differences in rate of progress between two interventions. One intervention provided visual support using color-coded screens and syntactic slots for grammatical and semantic sentence elements (Group 1, Computer-Assisted Intervention, $n = 11$). The other intervention provided visual support through objects in play, books, and picture cards with actions for semantic elements only (Group 2, Table-Top Intervention, $n = 11$). Both interventions targeted accurate production of a basic simple sentence (i.e., third person singular present progressive sentences). Twenty-two, 3- to 5-year-old preschoolers with specific language impairment (SLI) participated in 20-minute once weekly sessions. Both interventions included sentence breakdown (i.e., breaking sentences into subject, verb, object components that are trained to an 80% criterion) and build-up (i.e., putting the entire sentence together). Rate of progress in intervention was monitored for (a) efficiency (first session that the 80% criterion was achieved) and (b) syntactic growth (movement beyond the basic simple sentence level). Blinded assessors scored session-to-session data to establish potential differences in rate of progress between groups. The results showed that Group 1 outperformed Group 2 for efficiency and syntactic growth. This study demonstrated that use of multiple visual supports in expressive grammar training facilitated a therapeutic advantage in session-to-session grammatical learning for preschoolers with SLI.
Key words: *cognitive resources*, *expressive grammar deficits*, *preschoolers*, *session-to-session outcomes*, *specific language impairment*, *visual support*

CHILDREN WITH specific language impairment (SLI) require and benefit from appropriately designed interventions to alleviate burdens on cognitive resources (e.g., speed of processing, storage and retrieval of information) that could ultimately lead to improvements in language learning (Deevy & Leonard, 2004; Leonard, Deevy, Fey, & Bredin-Oja, 2012). Such interventions are needed particularly for facilitating grammatical skills

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development (Cleave & Rice, 1997; Leonard, 1998; Leonard, Camarata, Pawlowska, Brown, & Camarata, 2006, 2008). Consequently, the identification and understanding of underlying mechanisms that have a negative impact on grammatical learning in children with SLI, and alternatively, the identification and understanding of potential learning supports, is essential for designing effective and appropriate evidence-based intervention programs addressing core areas of impairment within this population (Leonard et al., 2007, 2012; Washington, 2007, 2010).

SPECIFIC LANGUAGE IMPAIRMENT AND COGNITIVE RESOURCES

The selection of a sound theory or umbrella of related theories supporting intervention approaches is important for clinicians working with children with language disorders (Justice & Fey, 2004; McCauley & Fey, 2006; Poll, 2011). Children with SLI, by definition, are thought to experience more difficulties processing linguistic information than other children (Archibald & Gathercole, 2006; 2007; Deevy & Leonard, 2004; Leonard et al., 2012). It is hypothesized that the underlying deficit associated with SLI may be linked to limits in phonological short-term memory (pSTM), working memory, processing speed, and other cognitive resources, such as attention and information storage and retrieval (Archibald & Gathercole, 2006; 2007; Ellis Weismer & Evans, 2002; Gathercole & Baddeley, 1990a, 1990b; Kail & Salthouse, 1994; Lahey & Edwards, 1996; Lahey, Edwards, & Munson, 2001; Leonard et al., 2012; Montgomery, 2000; Montgomery, Magimairaj, & Finney, 2010).

In this article, we consider interventions that account for limits in cognitive capacity, which refers to the amount of computational space or energy necessary for completing a mental task (Kail & Salthouse, 1994), in children with SLI. There is evidence that cognitive capacity serves as a critical and facilitating mechanism in the language learning process (Gathercole & Baddeley, 1990a, 1990b; Leonard et al., 2007), which is reduced in children with SLI compared to age-matched peers (Leonard et al., 2012). Given that children with SLI have a reduced cognitive capacity and may experience increased cognitive load from the everyday demands of language processing, one approach to alleviating this load problem in intervention has been the use of additional supports (Leonard et al., 2012; Wener & Archibald, 2011). Evidence-based techniques for these additional supports include the use of prompting, reinforcing, repetition, emphatic stress, and visual cues to help keep relevant information more salient (Camarata, Nelson, & Camarata, 1994; Cleave & Rice, 1997; Ebbels, 2008; Ebbels & van der Lely, 2001; Fey, Long, & Finestack, 2003). Visual cues are of particular interest because they provide a cross-modality mechanism for encoding, which may be less affected by the linguistic deficits that characterize SLI (Ebbels, 2008; Ebbels & van der Lely, 2001; Wener & Archibald, 2011; Zwitman & Sonderman, 1979). They also can be maintained in the child's view, unlike acoustic cues, which are rapid and temporary (Cohen et al., 2005; Tallal et al., 1996).

VISUAL SUPPORT IN INTERVENTION

Evidence within the published literature for children with SLI demonstrates that interventions that incorporate visual support using computer- or paper-based tools have been effective in addressing linguistic difficulties (Cohen et al., 2005; Ebbels & van der Lely, 2001; Ebbels, 2008; Gillam et al., 2008; Leonard et al., 2006, 2008). For preschool and school-aged children with SLI, there is evidence demonstrating that use of visual encoding including colors, shapes, and a system of arrows to teach grammatical rules improved these children's comprehension and production of grammatical rules (Ebbels, 2008; Ebbels & van der Lely, 2001; Zwitman & Sonderman, 1979). Furthermore, use of visualization strategies coupled with rehearsal has been shown to lead to enhanced language outcomes following intervention (Gill, Klecan-Aker, Roberts, & Fredenburg, 2003). As such, with visual support, assistance in therapy can be successfully provided for the encoding of language information.

Visual cues are believed to have multiple facilitating mechanisms that could support cognitive capacity. They may reduce the memory load, encourage better quality encoding, reduce demands for processing quickly, and emphasize linguistic features (see Ebbels, 2008; Ebbels & van der Lely, 2001 for a discussion). Visual representation for sentence elements can include providing picture support for nouns and verbs along with markers for grammatical components, such as shapes or color-coded symbols. The use of such resources, coupled with repeated practice and guidance in therapy, could decrease the burden on cognitive resources (Washington & Warr-Leeper, 2006, 2011). Consequently, the use of visual cues in language intervention may be particularly beneficial for children with SLI.

The current study was conducted as a follow-up analysis to two prior studies using existing data gathered in those original studies. In the first study, we explored the effects of visual support during a 10-week expressive grammar intervention program with a sample of 34 preschoolers with SLI, 22 of whom received intervention. This intervention program targeted accurate production of third person singular present progressive sentences during weekly sessions that included *sentence breakdown*, where sentences were broken into the subject-verb-object components and *sentence build-up*, where the entire sentence was put back together. We included two different intervention types. The *computer-assisted* approach used visual support for grammatical and semantic sentence elements, and the *table-top* approach used visual support for the semantic elements only (Washington, Warr-Leeper, & Thomas-Stonell, 2011). In our primary study, we examined outcomes between intervention and no-treatment waitlist control participants and between the two intervention groups. We compared participants' expressive grammar raw total scores on the Structured Photographic Expressive Language Test-Preschool (SPELT-P; Werner & Kresheck, 1983) and a language sample scored using Developmental Sentence Scoring (DSS; Lee, 1974), at postintervention and at 3 months postintervention (Washington et al., 2011). Results of analyses of covariance revealed that intervention participants significantly outperformed no-treatment waitlist control participants on the SPELT-P and DSS. Effect sizes (using eta-squared, η^2, values) ranged from .69 at postintervention to .71 at 3 months postintervention for SPELT-P performance; for the DSS, values ranged from .47 at postintervention to .51 at 3 months postintervention. Our results also demonstrated statistically nonsignificant differences between the two different intervention groups (i.e., computer-assisted and table-top) on the SPELT-P and DSS.

In a follow-up study (Washington & Warr-Leeper, 2013), we investigated growth in spontaneous expressive grammar skills by comparing raw change language sample scores between the same groups of participants over time, that is, preintervention to postintervention, postintervention to 3 months postintervention, and preintervention to 3 months postintervention. Language sample scores used in these analyses were calculated using DSS (for percent error rates) and Mean Length of Utterance (Brown, 1973; Miller, 1981). Results of multivariate analyses of variance and follow-up tests revealed that preschoolers who received one of the two different interventions experienced greater change scores compared to the no-treatment waitlist controls on both measures. The multivariate effect size η^2 was 0.68. However, we did not find statistically significant differences in outcomes between the two intervention groups.

Our previous findings supported the use of visual supports versus no-treatment controls for improving children's grammar, but they have not revealed a particular advantage at therapy end points between *computer-assisted* and *table top* interventions, which differ in the type and level of visual supports for grammatical sentence formation. It may be, however, that qualitative differences existed in our intervention that were masked by our focus on end point outcomes. In particular, we are suggesting that intervention with multiple visual supports may result in a more efficient learning process, session to session that needs to be investigated (Washington & Warr-Leeper, 2011). The current study examined this possibility for the sample of preschoolers who participated in the primary research study by Washington et al. (2011).

THE CURRENT STUDY

Information on session-to-session performance during grammar therapy could provide evidence for learning in intervention (i.e., rate of progress) that is occurring, but is not being captured at terminal end points (e.g., postintervention and follow-up; pre- to postintervention). It has been suggested that the encoding of information provided using multiple visual support (i.e., for grammatical and semantic sentence elements) could be different from the encoding of information utilizing visual support for semantic elements only (Washington & Warr-Leeper, 2011). Thus, corresponding session-to-session performance, reflective of the encoding experience, that is, the amount of cognitive load or burden could lead to a differential learning effect. This effect could be manifested by rate of progress in intervention for efficiency, for example, when sentence breakdown is no longer required, and syntactic growth beyond that targeted in therapy (Washington & Warr-Leeper, 2011).

The main aim of our current study was to investigate potential session-to-session differences in expressive grammar outcomes for interventions that provided different types of visual support. We applied theoretical considerations surrounding the reduced cognitive capacity experienced by children with SLI. Consequently, we considered intervention techniques that could alleviate the cognitive load during intervention, thus impacting the maintenance and retention of grammatical language information, for example, use of repetition or rehearsal and visual support, during grammatical training. To achieve the study objective, we compared session-to-session data for the sample of preschoolers in the study by Washington et al. (2011) who received Computer-Assisted Intervention (C-AI) to preschoolers receiving Table-Top Intervention (TTI). The key intervention difference was that C-AI incorporated visual support for both grammatical and semantic sentence elements, whereas TTI included visual support for semantic elements along with emphatic stress for grammatical elements (cf. Fey et al, 2003). Because the key difference between interventions was the types of visual support provided, potential differences in grammar performance could be attributed to that feature. The following research questions were addressed in this study:

1. Does an intervention program that includes visual support for grammatical and semantic sentence elements in expressive grammar training facilitate a faster rate of progress session to session, that is, more *efficiency*, compared to an intervention program that utilizes visual support for semantic elements only in preschoolers with SLI with primary expressive grammar deficits?
2. Does an intervention that includes visual support for grammatical and semantic sentence elements in expressive grammar training facilitate a greater rate of progress session to session, that is, more *syntactic growth*, compared to an intervention program that utilizes visual support for semantic elements only in preschoolers with SLI with primary expressive grammar deficits?

Corresponding hypotheses were made as follows: (a) the intervention with visual support for grammatical and semantic sentence elements would result in greater efficiency than the intervention that did not; and (b) the intervention with visual support for grammatical and semantic sentence elements would result in greater syntactic growth than the intervention that did not.

METHODS

To answer the research questions, the 22 preschoolers who were randomly selected for intervention from the 34 preschoolers in the Washington et al. (2011) study were included in this article. A summary of the procedures and protocols related to these participants are discussed in the upcoming sections. More detailed information can be found in the original publication.

Participants

Enrollment into the study followed parental permission for each preschooler to participate. At preintervention, the 22 preschoolers ranged in age from 3;11 to 4;10 (years; months, $M = 52$ months, $SD = 3.1$ months) and were monolingual English speakers residing in rural and urban settings in Ontario Canada. Participants' parents described them as Caucasian ($n = 20$), Asian ($n = 1$), or other ($n = 1$). There were 16 boys and 6 girls. Given that the literature has demonstrated that interventions for expressive grammar may be more effective if children do not also have corresponding receptive language difficulties (Law, Garrett, Nye, & Dennis, 2012), we limited study criteria in the Washington et al. (2011) research to reflect that requirement. All preschoolers were identified with SLI with primary expressive grammar deficits after meeting the following criteria: (a) normal hearing; (b) absence of oral motor, neurological deficits, or pervasive developmental disorder; (c) within normal limits receptive language skills (i.e., standard scores ≥ 85) at the word level measured using the Peabody Picture Vocabulary Test IIIB (PPVT-IIIB; Dunn & Dunn, 1997) and the sentence level, measured using the Clinical Evaluation of Language Fundamentals-Preschool (CELF-P; Wiig, Secord, & Semel, 1992); (d) normal nonverbal cognitive skills (IQ ≥ 85) based on the Kaufman Brief Intelligence Test 2 (KBIT-2; Kaufman & Kaufman, 2004); and (e) expressive grammar skills at or below the 10th percentile, established using two measures, one a language test, the SPELT-P (Werner & Kresheck, 1983), and the other a spontaneous language sample collected and scored using DSS (Lee, 1974) criteria.

To facilitate equivalent numbers of preschoolers in each expressive grammar intervention group, half received C-AI ($n = 11$) and the other half received TTI ($n = 11$). Results of univariate analyses of variance (ANOVAs) revealed that the two intervention groups did not differ statistically ($p > .05$) on diagnostic measures for nonverbal cognitive skills (KBIT-2; Kaufman & Kaufman, 2004) and on receptive language skills at the word level (PPVT-IIIB; Dunn & Dunn, 1997) and sentence level (CELF-P; Wiig et al., 1992), as well as on an expressive grammar-language test (SPELT-P; Werner & Kresheck, 1983), and a spontaneous language sample (DSS; Lee, 1974). Participants also were not significantly different in age at preintervention. See Table 1 for participant characteristics.

Procedures

Assessment

At preintervention, preschoolers completed a 90-minute assessment session where they were individually tested using a battery of tests to achieve the goals of the Washington et al. (2011) study. This testing was completed to determine study eligibility. The assessment session was completed in a standard clinical setting in Ontario, Canada, with preschoolers' parents present. All assessments were completed by licensed speech-language pathologists (SLPs) or graduate students in speech-language pathology who were supervised by SLPs. These assessors were blinded to intervention group and the purpose of the study.

Intervention: Content and development

Two contrasted interventions were used in this research. Both the C-AI software program, My Sentence Builder, and a table-top

Table 1. Preschoolers Characteristics.

	Total Sample (*n* = 22)	Computer Assisted (*n* = 11)	Table Top (*n* = 11)
Age (months)	52.23 (3.10)	51.36 (3.00)	53.09 (3.08)
Gender			
Female	6	3	3
Male	16	8	8
PPVT-IIIB	103.18 (4.75)	103.64 (5.71)	102.73 (3.77)
CELF-P	102.05 (8.33)	103.36 (8.65)	100.36 (8.10)
SPELT-P[a]	11.18 (3.03)	10.09 (2.30)	12.27 (3.38)
DSS[a]	5.02 (.90)	4.81 (1.08)	5.21 (.66)
KBIT-2	110.36 (10.97)	112.27 (12.35)	108.45 (9.61)

Note. Means and (standard deviations) are reported. Scores represent standard scores (M = 100, SD = 15) on all measures except where indicated. *Note*. CELF-P = Clinical Evaluation of Language Fundamentals-Preschool; DSS = Developmental Sentence Scoring; KBIT-2 = Kaufman Brief Intelligence Test 2; PPVT-IIIB = Peabody Picture Vocabulary Test IIIB; SPELT-P = Structured Photographic Expressive Language Test—Preschool.
[a]Raw Score.

approach (TTI) incorporated visual support within drill-play and focused stimulation activities along with modeling and repetition. C-AI and TTI were similar in the their overall feature content which included two parts, each with corresponding subcomponents that addressed task demands: (a) Part 1—sentence breakdown (horizontal goal attack strategy), including three opportunities for the production of noun phrases in the subject and object slots and the verb containing present progressive form (e.g., is + main verb + ing) and (b) Part 2—sentence build-up including two opportunities for the full subject + verb + object production.

The inclusion of the horizontal goal attack strategy to language intervention, which requires the remediation of multiple errors over the course of treatment (Fey, 1986; Fey, Cleave, Long, & Hughes, 1993), facilitated the sentence breakdown. This meant that multiple sentence components could be targeted simultaneously within the syntactic frame of a present progressive sentence, one of the earliest developmental sentence types acquired (Valian, 1992). This strategy also allowed us to vary the task demand so that smaller production segments were required before the full sentence was elicited and subsequently produced. Furthermore, the preschoolers were provided with more time to process sentence elements needed to produce a grammatically correct sentence. The artificial nature of drill-play and focused stimulation with visual support provided repeated opportunities in a meaningful context to make the linguistic goals more salient.

Key intervention difference

C-AI and TTI offered participants different types of visual support in intervention. The key difference between the interventions was that C-AI offered visual support in two areas: (1) grammatical elements including articles, verb structures, and bound morphemes, including where they should be inserted into the target sentence and (2) the semantic elements in the form of cartoon-like pictures (i.e., subject noun, verb action, and object noun). Using C-AI, abstract symbols needed to support grammatical representation could be illustrated using computer technology.

In contrast, the TTI visual support offered was limited to one area, that is, iconic representations of semantic elements using pictures and toys, with emphatic stress used to highlight grammatical elements. So, while the use of computers in C-AI may have been appealing to preschoolers, it also offered opportunities for different types of visual support in expressive grammar intervention for the production of grammatically correct sentences. It is important to note that the C-AI did not prompt more complex sentences than TTI; however, the on-screen color-coded syntactic slot-filler categories did signal to children that information needed to be added to make the sentence complete. In turn, this type of visual support could also encourage children's attempts to expand their sentence productions (e.g., using adjectives, conjunctions, adverbs, prepositions).

Computer-Assisted Intervention

My Sentence Builder is an author-designed and developed computer program that includes socially focused content embedded in syntactic slot-filler activities for the production of sentences (Washington & Warr-Leeper, 2006). There are seven color-coded screens containing visual images to support production: sentence creation, subject selection, verb selection, object selection, sentence selection, animation production containing audio recordings of actions, and a grammatical morpheme screen (see Figure 1 and the Supplemental Digital Content, available at http://links.lww.com/TLD/A23). The syntactic slot-filler technique chosen for the computer program was adapted from earlier paper versions, such as the Fitzgerald (1949) and the Fokes Sentence Builder (1976). Using this technique, grammatical and semantic components are orally and visually categorized into various grammatical slots (e.g., who, is doing, what/where) to facilitate comprehension and production.

The purpose of this categorization was to provide visual supports that highlight core sentence elements that are potentially missed by children with SLI. Cartoon-like nouns are illustrated on color-coded "who" and "what/where" screens and verbs from on an "is doing" screen. Inflectional morphemes (e.g., "ing") and function words (e.g., "the," "a"), illustrated in triangles, are also included to help form grammatically correct and complete present progressive sentences. Using the syntactic slot-filler technique, sentences are created by inserting semantic elements (e.g., subjects and verb actions) into predetermined slots. Therefore, visual support of each element (i.e., grammatical and semantic) in the sentence to be produced is provided.

With SLP support and verbal guidance, C-AI preschoolers moved from color-coded screen to screen while selecting elements needed to create a grammatically correct sentence. For example on the red screen, participants viewed the subjects to be chosen for insertion into its slot in the sentence box (see Figure 1). Thus, participants were able to observe repeatedly the location of the "who," the "is doing," and the "what" (noun and verb pictures) along with grammatical elements (*is*, *ing*, *the*—depicted in triangles) in a sentence. Using this approach, there was a slow deliberate construction of each sentence component to provide these participants with increased time to process and produce grammatical information.

Table-Top Intervention

The table-top program consisted of typical conventional language training procedures utilized in SLP-preschooler dyads. In lieu of the computer time, visual supports in intervention were provided by turning the pages of books (e.g., Mercer Meyer Me Too) along with using objects in play (e.g., felt doll house pieces) and picture cards with actions (e.g., Super Duper cards) to support grammatical productions in a drill-play format that offered repeated opportunities of focused practice. Emphatic stress, a recommended technique for orally stressing language targets (cf. Fey et al., 2003), was included to facilitate attention to the subject, verb, and object sentence components, including grammatical morphemes. Visual support for the grammatical

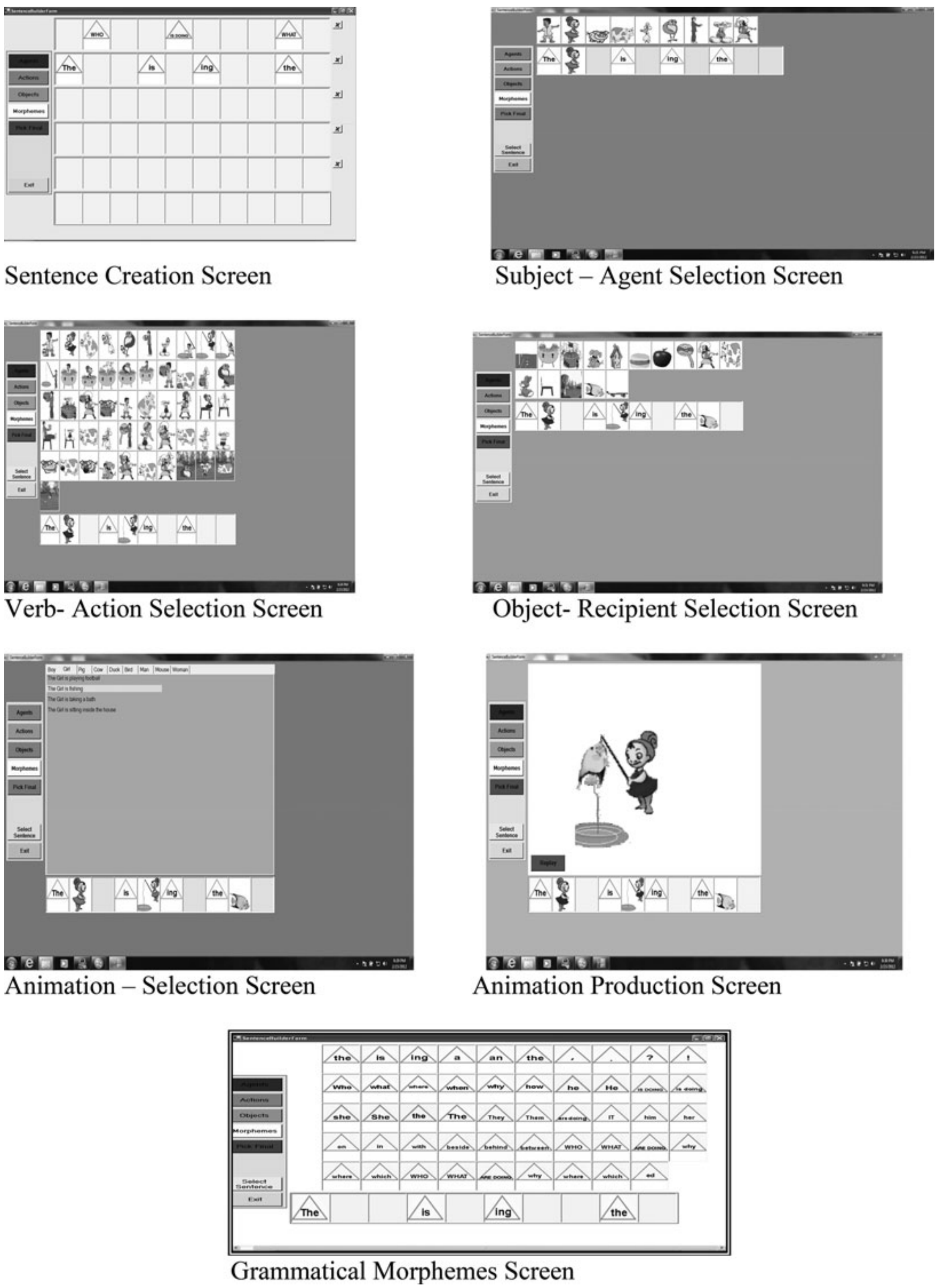

Figure 1. My Sentence Builder screens illustrated for the creation of "The girl is catching the fish."

morphemes (e.g., *ing*, *the*), however, was not provided. Using this approach, burden on cognitive resources was believed to be alleviated by the support of objects in play, including books and picture cards; emphatic stress; and the step-by-step procedure to elicit each component and then the entire sentence.

Implementing the intervention

Preschoolers participated in 20-minute expressive grammar therapy sessions once weekly for 10 weeks that targeted present progressive sentence production. We used a 10-week intervention program because there is evidence that if the interventions for expressive grammar lasted for at least 8-weeks, these interventions were found to be more effective than if they lasted for a shorter time period (Law et al., 2012). The following intervention procedure was used in both interventions during each session: (a) an introduction to the expected routine was made, followed by a 2- to 7-minute practice block; (b) each sentence element (subject noun phrase, verb, object noun phrase) was elicited individually (*sentence breakdown*) using the following questions: subject—"Who do you want to play with?," verb—"What is s/he doing?," object—"What does s/he want to play with?"; (c) each session continued to follow the same procedure until 80% accuracy on average over two consecutive sessions was achieved for each breakdown component; and (d) at the beginning of the subsequent session, participants were asked only to engage in *sentence build-up* ("Put it all together"). The inclusion of all four steps in the intervention sessions meant that multiple goals (i.e., sentence elements) were targeted simultaneously, which is reflective of a horizontal goal attack strategy. No further *sentence breakdown* was required once the 80% criterion was achieved. Results of independent samples t tests revealed that TTI participants had more production opportunities on average for sentence breakdown, $t(20) = 2.11$, $p = .048$ and build-up, $t(20) = 3.16$, $p = .005$ than C-AI participants. See Appendix A for a sample intervention routine.

Intervention fidelity

The first author provided all intervention sessions. Intervention fidelity was established using 20% of sessions that were randomly observed and recorded to determine adherence to a preestablished protocol. On the basis of the observations of the 44 sessions (22 for C-AI and 22 for TTI), the interventionist adhered to the protocol 100% of the time.

Rate of progress in intervention

Preschoolers' session-to-session performance was recorded electronically and transcribed online to facilitate future scoring by blinded assessors (i.e., graduate students in speech-language pathology). Rate of progress in intervention was monitored for both efficiency and syntactic growth. To monitor efficiency of intervention (i.e., achievement of the 80% criterion for each of the breakdown components), the session at which sentence build-up only occurred was documented. To track syntactic gains beyond the basic simple sentence level, complexity of sentences produced—an index of syntactic growth—was also monitored. Specific developmental types abstracted from Davis (1937) and McCarthy (1930) were used to code sentence complexity (SC). This approach was used rather than a more recent approach because it (a) permitted consideration of developmental sentence types; (b) permitted specific coding of sentences; and (c) was more flexible in the inclusion and selection of sentences, because we did not adhere to a specific sampling criteria for sentences. Each SC code corresponded to a specific numerical value, ranging from "1" (agrammatical production) to "9" (elaborated compound-complex production). As noted earlier, preschoolers were provided with two opportunities at sentence build-up to produce the target sentence correctly. Thus, to track SC, the better of the two sentences produced at build-up was used to establish syntactic growth.

An SC score, based on a devised mathematical formula (described later), was assigned to sentences produced at sentence build-up for sessions 1, 5, 6, and 10. These sessions were selected because they represented the beginning, midpoints, and end of intervention, respectively. Higher SC scores are better than lower SC scores, suggesting better SC performance. The formula used was as follows: $SC_X = \sum a(B)$ where "SC" represents SC score, an index of syntactic growth; "x" is the selected intervention session (i.e., 1, 5, & 6, or 10); "a" represents the assigned value for a sentence type from one to nine; and "B" represents the percent use for each sentence type. For example, if 10 sentences were selected for session 1 and 80% were assigned a score of "1" for complexity and 20% were assigned a score of "3" for complexity, then the sample calculation would be: $SC_1 = 1(80) + 3(20) = 140$. See Appendix B for the sentence scoring guide (Davis, 1937; McCarthy, 1930).

Design and data analysis

A between-groups randomized design was employed. To establish rate of progress in intervention, two different analyses were completed. First, an independent samples *t* test was conducted to evaluate whether statistically significant differences existed in the number of sessions required to meet the established criterion (i.e., 80% over two consecutive sessions) for vertical progression in intervention. Second, a 2 (Group: C-AI and TTI) X 4 (Time: Intervention Sessions 1, 5, 6, 10) mixed Model ANOVA was used to test for differences in outcomes (i.e., SC scores) between the two interventions for syntactic growth session to session.

A preset alpha level ($p < .05$) was used to establish statistical significance for both interventions. For the ANOVA, planned follow-up tests were completed for significant *F* values. A Bonferroni correction ($p < .013$) for each follow-up test was used to decrease the likelihood of a type 1 error (Portney & Watkins, 2009). The variance in performance (effect size) explained by the independent variable (i.e., C-AI or TTI) was reported using eta squared η^2 values. To complete these analyses, all data were entered into the Statistical Program for the Social Sciences (PASW Statistics, 2012).

RESULTS

Rate of progress: efficiency

Results of the independent samples *t* test revealed significant differences between C-AI and TTI preschoolers' performance for the number of sessions taken to achieve the 80% criterion (i.e., the session that 80% accuracy on average over two consecutive sessions was achieved for each breakdown component), $t(20) = 2.95$, $p = .04$. Examination of mean performance indicated that preschoolers receiving C-AI ($M = 4.00$, $SD = .78$) were closer to session 4 when they achieved the 80% criterion, but TTI cohorts ($M = 5.18$, $SD = 1.60$) were closer to session 5. The 95% confidence interval for the difference in means ranged from 0.035 to 2.33, suggesting that these differences did not occur by chance. Performance for each intervention is illustrated in Figure 2.

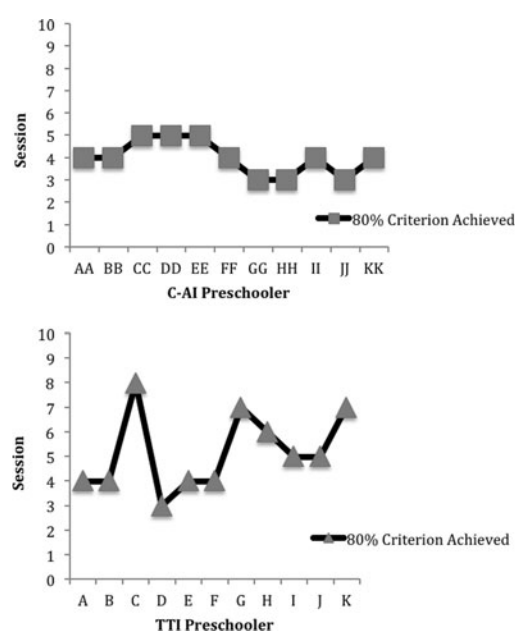

Figure 2. Session 80% criterion achieved for C-AI and TTI preschoolers. C-AI = Computer-Assisted Intervention; TTI = Table-Top Intervention.

Rate of progress: Syntactic growth

The mixed model ANOVA used to test for differences between SC scores of the two groups of intervention preschoolers met the preset alpha level. A significant interaction between intervention group and session was found, $F(3, 60) = 6.45$, $p < .001$, partial $\eta^2 = .70$, suggesting that groups differed across time (i.e., sessions). To establish the specific sessions at which groups differed, we conducted analyses at each of the four sessions of key interest, beginning (session 1), midpoints (sessions 5 and 6), and end (session 10) of intervention. Univariate ANOVAs served as the analyses of choice, reflecting follow-up tests to the mixed model ANOVA that examined differences in between-group scores (Portney & Watkins, 2009). The univariate ANOVA at session 1 did not meet the preset alpha of .013 for follow-up tests, $F(1, 20) = 3.15$, $p = .09$, $\eta^2 = .14$. However, follow-up tests at session 5, $F(1, 20) = 7.65$, $p = .012$, $\eta^2 = .28$; session 6, $F(1, 20) = 8.85$, $p = .007$, $\eta^2 = .31$; and session 10, $F(1, 20) = 8.28$, $p = .009$, $\eta^2 = .29$ met the preset alpha level. Pairwise comparisons of means revealed that C-AI preschoolers achieved statistically higher mean scores at sessions 5, 6, and 10 compared with TTI cohorts. See Figure 3 for mean SC performance at sessions 1, 5, 6, and 10. See Figures 4a and 4b for a sample SC performance across sessions. Sample sentences produced by C-AI and TTI participants at weeks 1, 5, 6, and 10 are listed in Appendix C.

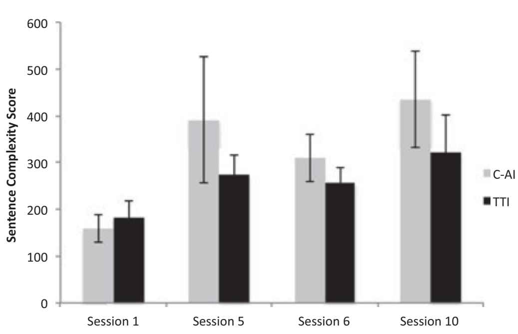

Figure 3. Mean performance at the beginning (session 1) midpoints (sessions 5 and 6) and end (session 10) of intervention for C-AI and TTI preschoolers. C-AI = Computer-Assisted Intervention; TTI = Table-Top Intervention.

DISCUSSION

Cognitive capacity in grammatical training is an important intervention consideration for younger and older children with SLI (Leonard et al., 2012; Washington et al., 2011; Washington & Warr-Leeper, 2013). This includes SLPs being cognizant of these children's capacity for attention, processing speed, strategies for processing and storage, rehearsal, and retrieval (Leonard et al., 2012). As clinicians, we need to control what we do in intervention as well as how we do it. For example, the demands (i.e., cognitive load) placed on these children's language learning resources should be considered (Leonard et al., 2012). We should also choose specific procedures and elements for elicitation that help to increase the saliency of grammatical information. Ultimately, the interventions clinicians provide should support children with SLI with basic processing abilities that increase their attention to grammatical forms while also decreasing the burden on cognitive resources.

In the current study, we considered cognitive capacity for grammatical learning session to session using two different types of interventions, C-AI and TTI, which differed in the type of visual support provided, to examine rate of progress for efficiency and syntactic growth. Previous research has found no particular advantage for either C-AI or TTI at therapy end points (i.e., end of therapy and 3-months posttherapy) (cf. Cohen et al., 2005; Washington et al., 2011). However, learning in intervention, evidenced by rate of progress, could be occurring to support grammatical development, even though it is not captured at therapy end points. Information on rate of progress in intervention is useful in guiding and supporting SLPs' therapy decisions for different clients in different settings.

The interventions utilized in the current research included features such as visual a

Sentence Type Produced (Sentence Score)	Intervention Session ("Build-up" only = Session 4)			
	1_5	5_4	6_7	10_6
AG (1)	60%	-	14%	17%
BSS (2)	40%	-	-	-
ESS (3)	-	25%	72%	17%
CXS (6)	-	50%	14%	17%
E-CXS (7)	-	25%	-	50%
Sentence Complexity Score	**140**	**550**	**314**	**520**

b

Sentence Type Produced (Sentence Score)	Intervention Session ("Build-up" only = Session 5)			
	1_{10}	5_6	6_9	10_{14}
AG (1)	50%	16%	11%	29%
BSS (2)	50%	33%	11%	-
ESS (3)	-	17%	78%	64%
CXS (6)	-	17%	-	7%
E-CXS (7)	-	17%	-	-
Sentence Complexity Score	**150**	**354**	**267**	**263**

Figure 4. (a), Sample C-AI preschooler's (female, 4;6) performance at sessions 1, 5, 6, and 10. Scores are based on this preschooler's percent use of particular sentence types. Syntactic growth is depicted using increased shades of gray. The lowest syntactic level is "AG" (Agrammatical—light gray) and the highest is "EC-CXS" (Elaborated Compound-Complex—darkest gray). Subscript value represents the number of sentences selected to establish the sentence complexity (SC) score. C-AI = Computer-Assisted Intervention. (b), Sample TTI preschooler's (female, 4;6) performance at sessions 1, 5, 6, and 10. Scores are based on this preschooler's percent use of particular sentence types. Syntactic growth is depicted using increased shades of gray. The lowest syntactic level is "AG" (Agrammatical—light gray) and the highest is "EC-CXS" (Elaborated Compound-Complex—darkest gray). Subscript value represents the number of sentences selected to establish the SC score. TTI = Table-Top Intervention.

support and rehearsal in the form of multiple repeated opportunities for production at two levels, sentence breakdown and sentence build-up. Our techniques and procedures were designed to decrease the cognitive load by increasing the saliency of grammatical rules, thus making production easier. The key difference between interventions was that C-AI provided visual support for grammatical and semantic sentence details whereas TTI had restricted visual support for semantic details provided by objects in play, books, and picture cards. We hypothesized that this difference would lead to different encoding experiences during intervention that would be evidenced in differences in rate of progress session to session between the two groups.

The results supported our hypotheses in that there were clear performance differences between preschoolers with SLI who received C-AI with the greater number of supports for grammatical as well as semantic elements and those who received TTI, which provided support for the semantic elements only. Results of statistical analyses revealed that C-AI was associated with a faster rate of progress for efficiency and a greater syntactic growth session to session. On average, preschoolers enrolled in C-AI achieved the 80% criterion at session 4 whereas TTI preschoolers were one session behind at session 5. Preschoolers in

C-AI also experienced greater syntactic growth, showing higher levels of SC (i.e., productions beyond a basic simple sentence level), at the midpoints and end of intervention compared with their TTI cohorts.

The rationale for a therapeutic advantage

Children with SLI struggle with the storage and rehearsal process in language learning that helps to keep grammatical information maintained and refreshed (Leonard et al., 2007, 2012). External support to help facilitate maintenance and processing of grammatical information is therefore beneficial. The visual representations provided in C-AI for grammatical morphemes (e.g., *ing*, *a*, *the*) and semantic sentence components may have been an important feature in facilitating a decreased cognitive load session to session. Ultimately, the encoding of information for storage and processing may have been less burdensome for C-AI preschoolers because visual support for both grammatical and semantic sentence elements was provided, thus increasing the saliency of target stimuli.

Even though TTI preschoolers had more production opportunities at breakdown and build-up than C-AI preschoolers, they may have had to deal with more cognitive load. Thus, rehearsal opportunities with one type of visual support may have been insufficient in facilitating greater efficiency and complexity outcomes for TTI preschoolers. Furthermore, the slow deliberate construction of each sentence offered during C-AI component (i.e., using the color-coded syntactic slots) may have provided these participants with increased time to process and produce grammatical information. This increased time may have been beneficial in supporting the generation of creative expansions (i.e., beyond that illustrated on screen) and more complex sentences compared to the TTI condition. It appears therefore that intervention feature we believed to be the key ingredient, which was represented by the types of visual support and number of features supported, may have facilitated a therapeutic advantage in grammatical training for C-AI preschoolers, consistent with our hypotheses.

In summary, for the process of learning in expressive grammar intervention, there may be advantages associated with the features of the C-AI program (e.g., visual representation for abstract grammatical components, including inflectional markers and semantic components and the slower pace) that help to address difficulties in resource allocation and rate of processing for preschoolers with SLI. Attention to these cognitive skills is considered to be important in the language learning process (Archibald & Gathercole, 2007; Leonard et al., 2007, 2012).

Limitations and future directions

The main limitation of this study was that we did not first determine if the preschoolers experienced specific cognitive deficits in working memory, speed of processing, and pSTM. That said, we applied a well-researched theoretical perspective on grammatical learning and cognitive capacity for the population of interest. Future studies could address this limitation by evaluating cognitive resources at the outset of intervention. More evidence for the relationships between cognitive capacity and language functioning before and after intervention could be provided.

Another limitation was that the sample of preschoolers was small and participants were recruited based on their primary expressive grammar deficits. This made them appropriate for the intervention, but it impacts the external validity of this study by limiting the generalizability of findings to the larger population of children with SLI. Future studies could be designed to address this limitation using a larger and more representative sample so that findings can be more broadly applied. We also acknowledge that because C-AI and TTI contained similar overall features in their interventions, there may have been a confounding of methods and that it may have been the computer-assisted delivery mode rather than the added visual cues for grammatical elements that made the critical difference. Consequently, although we can postulate, we have no certainty in knowing what the actual key variable was between the two interventions.

CONCLUSION AND CLINICAL IMPLICATIONS

The topic of SLI and interventions to address cognitive constraints is developing within the speech-language pathology literature. We know that preschoolers with SLI require and do benefit from grammatical language interventions addressing deficits in expressive grammar functioning (Law et al., 2012; Leonard et al., 2008). Theoretical underpinnings for intervention approaches are an important consideration for designing evidence-based interventions (Justice & Fey, 2004; Poll, 2011). Evidence for the role of underlying cognitive processes in facilitating or hindering morphosyntactic development suggests that SLPs should be cognizant of these underlying mechanisms. The explicit support (e.g., varying of task demands along with multiple visual supports) and attention to grammatical features provided in specific types of interventions may facilitate more time to process and maintain information as well as increase preschoolers' awareness while also decreasing language-learning efforts.

The current research provides SLPs with evidentiary support for more choices of scientifically supported intervention tools for use with preschoolers with SLI. For SLPs in clinical practice who are able replicate the C-AI procedures and tools, there is the advantage of a faster rate of progress in intervention. SLPs whose clinical setting(s) do not support computer-based intervention may decide to replicate the TTI procedures and tools. These SLPs need to consider modifying the procedures of the TTI approach by moving more slowly in intervention through use of multiple types of visual support for grammatical and semantic sentence elements. This change could support the attainment of equally complex sentences as experienced by the C-AI preschoolers in the current study. Ultimately, important gains in grammatical learning during expressive grammar intervention are possible when we consider what, how, and why we do what we do in intervention for preschoolers with SLI.

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Appendix A. Sample Intervention Routine

SLP: "We are going to talk about boys or girls doing different things. You will have lots of time to practice telling me what different boys or girls are doing. I will be helping you a lot. Now let's start."

A 2- to 7-min practice block followed before the training period began (i.e., the scored portion). This practice was completed to help establish the expected routine.

SLP: Who do you want to play with?

Preschooler: girl.

SLP (using emphatic stress or pointing to grammatical image): girl?

Preschooler: The girl.

SLP: What is the girl doing? The girl . . .

Preschooler: catching.

SLP (using emphatic stress or pointing to grammatical image): catching?

Preschooler: is catching.

SLP: What is the girl catching? The girl is catching . . .

Preschooler: a fish.

SLP: Now put it all together.

Preschooler: The girl + is catching + a fish.

Once the target sentence was produced accurately, preschoolers enrolled in Computer-Assisted Intervention were able to observe an animation of the sentence; while preschoolers enrolled in Table-Top Intervention engaged in play to have the characters complete the action.

Appendix B. Sentence Scoring Guide

Score	Description	Example
1	Agrammatical or incomplete sentence (AG/IC)	He is catch fish.
2	Basic Simple Sentence (BSS) [with unelaborated phrase] ☐ Single independent clause no dependent clauses ☐ An independent clause contains a subject and a predicate and CAN stand on its own	He is fishing. The boy is fishing. The girls are playing soccer.
3	Elaborated Simple Sentence (ESS) [with elaborated phrase] ☐ Single independent clause no dependent clauses (see definition—score 2) ☐ Use of modifiers and/or contains compound subject or predicate and phrase	The big boy is catching the big fish. He is catching the big fish
4	Compound Sentence (CS) ☐ Two or more independent clauses joined by a conjunction *and, but, so*) ☐ (see definition independent sent—score 2)	The boy is catching a fish [indept clause] and [conj] he is kissing the frog [indept clause]
5	Elaborated Compound Sentence (ECS) ☐ Two or more independent clauses joined by a conjunction (*and, but, so*) ☐ Use of modifiers(e.g., adj, preps) and/or Contains compound subject or predicate and phrase	The big boy is catching a small fish [indept clause] and [conj] he is kissing the very large frog [indept clause]
6	Complex Sentence (CXS) ☐ Independent clause and one or more dependent clauses ☐ (see definition independent sent—score 2) ☐ A dependent clause has a subject and a predicate EXCEPT it begins with a subordinating word and it CANNOT stand alone (after, although, as if, as, so [that]).	The boy is catching a fish because he likes to eat fish.
7	Elaborated Complex Sentence (ECXS) ☐ Use of modifiers (e.g., adj, preps) and/or Contains compound subject or predicate and expanded phrase	The big boy is catching a small fish because he likes to eat small fish.
8	Compound-Complex Sentence (C-CXS) ☐ A sentence that contains two or more independent clauses (compound sentences) and at least one dependent clause (complex sentence)	The boy is catching the fish and he is eating it because he likes to eat fish.
9	Elaborated Compound-Complex Sentence (EC-CXS) ☐ Use of modifiers (e.g., adj, preps) and/or Contains compound subject or predicate and expanded phrase. Joins two independent clauses, one of which contains a subordinate clause.	The big boy is catching the small fish and he is eating it because he likes to eat a small fish.

Appendix C. Sample Sentences Produced by Participants in Each Intervention Group

Week	C-AI Sample Sentence	TTI Sample Sentence
1	Boy is catching fish.	Mommy is read a book.
5	He is playing football with his big friends because he likes to play.	The boy is catching a small fish.
6	The girl is playing football with her big brother.	She is sitting on a chair watching TV.
10	He is playing football because he likes to play with his friends all the time.	The boy is taking a bath in the bathtub, 'cause he's dirty.

Note. C-AI = Computer-Assisted Intervention; TTI = Table top intervention.