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The emergence of clause construction in children who use SGDs

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Abstract

This study aimed to detect patterns in clause construction structural changes produced by four participants aged 9;5 to 13;7 (years;months) with motor speech disorders who use speech-generating devices. Sequences of adult–child interactions, drawn from the data of a larger study focused on enhancing vocabulary and grammar skills (Soto & Clarke, 2017), were examined. This current study comprises a secondary analysis of a corpus of 29 conversations totaling 808.36 min, analyzing clause structures by type, linguistic complexity, and intensity of adult prompts (number of turns). Results show that, over time, the participants' clause structure complexity increased through addition of phrase-internal elements such as inflections, articles, and prepositions. Use of specific grammatical elements followed the developmental stages observed in children with typical development (Brown, 1973). For all participants, the personal pronoun *I* (first-person singular) emerged before *she*, *he* (third-person singular), and *we* or *they* (plural). Participants with the highest number of adult–child co-constructed clauses also had the highest number of well-formed clauses. The intensity of adult prompts increased as clause structures became more complex and as participants needed more support. Implications for practice and theory are discussed.

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¹Gateway is a product of the Communication Technology Resources Company of Highlands, NJ, www.gatewaytolanguageandlearning.com

²Unity is a product of the Prentke Romich Company of Wooster, OH, www.prentrom.com/prc_advantage/unity-language-system

³The Dynavox is a product of the DynaVox Mayer-Johnson Company of Pittsburgh, PA, www.dynavoxtech.com/product

⁴The Vantage is a product of the Prentke Romich Company of Wooster, OH, https://www.prentrom.com/prc_advantage

Keywords

Clause construction; language development; speech-generating devices; augmentative and alternative communication

Little research has been done on the linguistic practices of children with motor speech disorders as they begin to formulate clauses. The purpose of this study was to understand how and when children with motor speech disorders who use speech-generating devices (SGD) shift from uttering single verbs to constructing well-formed clauses.

A *clause* is defined as “any unit that contains a unified predicate ... that expresses a single situation (activity, event, or state)” (Berman & Slobin, 1994, p. 660). Scholars who subscribe to the usage-based approach to language acquisition adopted in this paper (e.g., Berman & Slobin, 1994; Tomasello, 1992) are interested in understanding changes in clause complexity from the time children first produce the basic unit of the clause, typically a verb, until they construct adult-like clauses.

From a usage-based perspective, the structure of language emerges from language use. Children rely on their cognitive skills (intrinsic) and adults’ input (extrinsic) to learn language structure by detecting patterns and extracting words and morphemes from the speech stream (Lieven, 2010; Tomasello, 2003). Thus, the distribution and frequency properties of the child-directed speech input play a major role in the emergence of linguistic constructions (Romberg & Saffran, 2010; Yurovsky, Yu, & Smith, 2012). The assumption underlying the usage-based approach is that, in development, form and function interact with each other. The term *form* refers to various types of linguistic devices ranging from grammatical morphemes and bound inflections to interclausal connectives and syntactic constructions that differ in their complexity levels in acquisition; whereas the term *function* refers to a range of functions such as turn-taking and question–answer pairs during construction (Berman & Slobin, 1994).

Although there is an extensive body of research on the linguistic practices of children with typical development, evidence for the linguistic practices of children who use aided augmentative and alternative communication (AAC) is only emerging. The next sections summarize what is known about the grammatical development of these two groups.

Grammatical development of children with typical development

Children with typical development can express more information as they learn more complex linguistic structures (Clark, 2016). Over time, children add more complexity to each utterance, for example moving from the utterances *More cookie* to *I need another cookie*. Likewise, children go from single-word utterances to word combinations and verb islands (i.e., each verb appears in only one or a small number of constructions) before they construct more adult-like constructions (Clark, 2016; Tomasello, 1992).

Lexical growth and grammatical complexity are strongly correlated, and the growing lexicon provides the foundation upon which grammatical principles emerge (Dixon & Marchman,

2007; Goodman & Bates, 2013). In other words, a critical mass of vocabulary is required to boost the development of grammar, and precise lexical accomplishment is required for the emergence of specific abstract patterns. Brown (1973) found that after establishing a vocabulary of at least 50 words, children began to combine two or more words, and a consistent order of 14 grammatical morphemes emerged. For example, the verbal inflection *-ing* emerged first, followed by the verbal past inflection *-ed*, and finally the third-person singular *-s*.

The verb, the core element of the clause, is a crucial component in learning grammar and expressing complex meaning (Berman & Slobin, 1994; Tomasello, 1992). To construct a clause, children need to start using verbs, which they typically produce at the age of 2 years. Children move from one stage to another by learning the conventional constructions of their language, such as how to use verbal inflections (e.g., *-ing*, *-ed*, *-s*) and order arguments in a clause. To illustrate, English requires subject-verb-object (SVO) word order. Research has shown that the first multiword utterances English-acquiring children produce follow both adult SVO word order and adult thematic patterns, which puts the agent before, and the patient after, the verb (Thothathiri & Snedeker, 2011), as shown in Example 1:

- (1) I eat sandwich
 S V O
 agent–action–patient

Later, children add greater precision to clauses by specifying more complex semantic roles, such as locative and instrument (e.g., *I eat sandwich in the kitchen* and *I eat sandwich with fork*; Bloom, Lahey, Hood, Lifter, & Fiess, 1980). Despite individual differences, there are shared trajectories of acquisition in the first five years of life. For example, one of the most stable measures of early syntax in Brown's Stages 1–4 is the mean length of utterance (MLU), measured in terms of number of morphemes. As children move from one stage to another, the number, length, and complexity of their utterances increase, as does the number of grammatical morphemes produced, resulting in higher MLU scores (Brown, 1973; Miller & Chapman, 1981). They develop syntactic complexity over time by modifying nouns with adjectives and quantifiers (e.g., *red block*, *more block*) and modifying verbs with adverbs (e.g., *run faster*; Clark, 2016).

Grammatical development of children who use aided AAC

Children who use aided AAC face learning not only the linguistic structures described for children with typical development, but also how to use their specific communication aid and its representation system (Beukelman & Mirenda, 2013). The asymmetry between the input users receive (receptive language acquired through the aural modality) and output they are able to produce (expressive language expressed via graphic symbols), along with intrinsic (e.g., motor and cognitive skills) and extrinsic (e.g., level of practice and type of device) factors affect the children's grammatical performance.

The linguistic behavior of children who use aided AAC often includes utterances that are telegraphic and lack grammatical morphemes. These children are reported to experience a

wide range of vocabulary and grammatical difficulties beyond those predicted from their individual cognitive differences and language competence (Binger & Light, 2008; Blockberger & Johnston, 2003; Light & McNaughton, 2014; Smith, 2006, 2015; Sutton, Soto, & Blockberger, 2002).

Three hypotheses in the AAC field attempt to explain the relationship between spoken and graphic-symbol utterance structures: the compensation, modality-specific, and linguistic-verbal modality hypotheses. The first two hypotheses do not necessarily contradict each other; both offer explanations for the unusual syntactic pattern production found in children who use aided AAC. The compensation hypothesis suggests the atypical structure of graphic-symbol messages reflects the compensation strategies graphic-symbol users and their partners use to navigate cognitive, physical, and linguistic barriers during interaction (Soto, 1999; Sutton et al., 2002). The modality-specific hypothesis states that the graphic-symbol modality itself directly influences the structure of constructed utterances due to the specific constraints of the visual graphic mode because most graphic symbols do not share the features of linguistic systems (Smith, 2015; Sutton et al., 2002). The modality-specific hypothesis predicts that the production of graphic-symbol utterances will differ from what one might expect based on spoken-word order (Soto, 1999; Sutton et al., 2002; Trudeau, Sutton, Dagenais, de Broeck, & Morford, 2007). The linguistic-verbal modality hypothesis suggests that the verbal modality is superior to the graphic-symbol modality in terms of utterance organization. This hypothesis assumes the production of messages with graphic symbols is based on a mental representation first constructed in a verbal structure and then transposed into graphic symbols. It predicts that when taught to use grammatical markers, the basic structure of the utterance produced via graphic modality will follow the structure of spoken-language grammar, modified based on the specific AAC system (Smith, 2015; Trudeau et al., 2007).

Recent studies on the morphosyntactic acquisition of children who use AAC support the linguistic-verbal modality hypothesis. These studies used technology with access to the full range of grammatical markers. Following advanced intervention strategies, systematic language intervention, or short training, the children generated and understood different types of clauses and improved their grammatical skills (Binger, Kent-Walsh, King, Webb, & Buenviaje, 2016; Kent-Walsh, Binger, & Buchanan, 2015; Soto & Clarke, 2017). For example, Soto and Clarke (2017) found that a systematic conversation-based intervention improved the expressive vocabulary and grammatical skills of eight participants aged 8 to 13 years with motor speech disorders who relied on AAC. Before the language intervention, the study participants had communicated mostly with one-word utterances categorized as nouns. During and following the intervention, the grammatical acceptability of the children's spontaneous clauses, including use of pronouns, verbs, and bound morphemes, improved. Often, such improvement was achieved through the use of strategies to construct grammatically correct clauses via SGD in conversation.

Such strategies include using prestored phrases and co-construction. A *prestored phrase* is a unique SGD feature that allows the user to deliver a multiword phrase by clicking a single button. Prestored phrases enhance communication speed and maintain conversation flow (Rydeman, 2010; Todman & Alm, 2003). *Co-constructed clauses* are constructed across

multiple turns with support of adult prompts and elicitation behaviors (Savaldi-Harussi & Soto, 2016, 2018; Soto, Hartmann, & Wilkins, 2006; Soto, Solomon-Rice, & Caputo, 2009). The co-construction strategy is also observed in conversations between adults and young children with typical development, with the adult scaffolding the child's language by enhancing language forms (Scollon, 1976). *Autonomously constructed clauses*, created by selecting different symbols in the SGD without adult assistance, are feasible with appropriate technology and adequate training.

Despite these strategies, to date, there has been no well-organized evidence on stage changes in clause structure in users of aided AAC (i.e., apart from a few longitudinal single-case studies that described general language development and vocabulary growth aspects (e.g., Brekke & von Tetzchner, 2003; Soto & Seligman-Wine, 2003). The goal of the current research was to examine further Soto and Clarke's (2017) corpus of data and report structural changes of clause constructions produced by four participants with motor speech disorders who used SGD, from when they first started to use the basic clause unit (i.e., a predicate) until they constructed a multiword clause. Each participant's corpus included six to eight conversational interactions with a familiar adult before, during, and after they participated in the intervention. The aim of the current study was to answer three questions: What types of clause constructions did participants produce in terms of co-constructed and autonomous clauses, syntactic constituents (SVO), phrase-internal elements, and types of grammatical errors? How did the frequency and complexity of clause constructions change over a period of up to 10 months? How did the intensity of the adult prompting affect the participants' linguistic behavior (e.g., how many clauses were co-constructed with the adult and how many turns did each require)?

Method

Research design

This study involved a secondary analysis of language transcripts collected as part of a larger study designed to investigate the effects of a conversation-based intervention on the expressive vocabulary and grammatical skills of children with motor speech disorders who used SGD (Soto & Clarke, 2017).

Participants

The sample for this secondary analysis sample consisted of data from four of the eight participants in Soto and Clarke's (2017) study: two females, (Participants A and D), and two males, (Participants B and C). All were aged 9–13 years. (Soto and Clarke further detailed each participant's description, as well as the data quality, transcription, and coding.) All participants in the current study attended public schools in the United States that had special programs for children who use AAC, used their own SGD (with English output), and had been rated at Level III on the AAC Profile (Kovach, 2009). The AAC Profile measures skills in four areas of AAC competence: operational, linguistic, social, and strategic (Light, 1989). Level III indicates the participant selected targeted symbols with few prompts (operational), was beginning to engage in dialogue and combine words to create simple phrases (linguistic), used AAC for social interaction to comment and greet friends (social), was

familiar with the vocabulary in the device, and may have used telegraphic messages but understood the importance of selecting the correct vocabulary and being understood by the communication partner (strategic; Soto & Clarke, 2017).

The four participants in the current sample (Table 1) also shared the following characteristics: they formulated messages in their SGD via direct-selection techniques, used English as their dominant language, had hearing and vision within normal limits and no diagnosis of intellectual impairments, scored less than 50% for speech intelligibly on the Index of Augmented Speech Comprehensibility in Children (Dowden, 1997) to familiar partners in unknown contexts, communicated mostly through single-word utterances in unstructured interaction, and had age-equivalent scores for single-word receptive vocabulary lower than their chronological age and very poor comprehension of grammatical morphemes. School records confirmed that before the language intervention, the participants were nonverbal or minimally verbal and communicated mostly through SGD, generating single-word utterances categorized mostly as nouns and a few verbs, with little evidence of grammatical markers such as inflections or prepositions. Although formal tests were not administered, none of the participants had a diagnosis of intellectual impairment.

After a baseline period, each participant engaged in a conversation-based intervention where clinicians used verbal scaffolding strategies in the context of personally meaningful conversations. Intervention sessions were implemented twice a week for up to 12 weeks (see Soto & Clarke, 2017, for a detailed description of intervention procedures). The linguistic targets included key structures essential to early clause formation and grammaticalization and included verbs, pronouns, bound morphemes (e.g., third person *-s*, plural *-s*, past *-ed*, and present progressive *-ing*); and other frequently used words such as prepositions, articles, adjectives, and adverbs. The clinicians also modeled words that were child-specific and relevant to the conversation.

During generalization sessions designed to monitor the generalization of linguistic targets, each participant conversed with a familiar adult who was a member of the child's educational team. The participants had the same adult partner during all generalization sessions, and the adults varied in the extent of their AAC training. Neither the participants nor the adults were given any instructions as to how or what to converse about; they were only instructed to engage in conversation as they normally would. The generalization sessions, therefore, occurred under conditions different from the baseline and intervention sessions. Generalization sessions happened once prior to the start of the intervention, every six intervention sessions, and, when possible, at 2-, 4-, and 8-week intervals post-intervention.

Throughout the intervention and generalization sessions, the participants improved their production of clauses and linguistic targets. The coding and analysis in the current study were designed to further explore the structural changes of clauses produced by the children and supported by the adults.

Procedures

All baseline, intervention, and generalization sessions had been videotaped and transcribed (Soto & Clarke, 2017) using the conventions of the systematic analysis of language transcripts (SALT®; Miller, Andriacchi, Nockerts, Westerveld, & Gillon, 2012). For the current study, only the generalization sessions of the four selected participants previously described were included for analysis. The data included 29 transcripts representing a total of 808.36 min (13.5 hr) of interaction. The total number of conversations (transcripts) and length for each participant were Participant A ($n = 8$; 200.4 min), Participant B ($n = 7$; 209.8 min), Participant C ($n = 6$; 183.16 min), and Participant D ($n = 8$; 215 min).

Coding and analysis.—Using the transcript data, the types of clause constructions the participants produced, the linguistic complexity of the clauses, and the intensity of the adult prompts (number of turns) during a co-constructed clause were analyzed manually.

Clause construction types.—Coding of the participant-authored constructions differentiated between prestored, co-constructed, and autonomously constructed clauses. Prestored clauses were messages participants constructed during the intervention sessions and served as personal narratives (e.g., “*Tio John, Mom, and I went to see San Francisco*”) or generic social messages (e.g., “*How are you*” and “*My favorite team is*”). They produced these clauses by activating a single button (symbol) in the device to voice the message. Co-constructed clauses were messages constructed by the participants across multiple turns with support of adult prompts and elicitation behaviors. Autonomously constructed clauses were messages generated during the conversation in one uninterrupted turn without support from a conversation partner.

Both co-constructed and autonomously constructed clauses require a participant to select all clause constituents by selecting the buttons on the device that represent the specific constituents. For study purposes, co-constructed and autonomously constructed clauses were clustered into one group called clause constructions. Prestored phrases and self-repetitions (of the same construction) were excluded from the syntactic and complexity analyses because the research questions tracked how the participants used different construction types in terms of morphosyntactic constituents over time.

Structures targeted.—Target structures were identified in each conversation. First, the basic clause unit was identified based on Berman and Slobin’s (1994) definition as any unified predication. For example, the verb *sleep* and the utterances *I run* and *is happy* were considered clauses. Next, the analysis assessed whether the identified basic unit was part of a larger turn-taking sequence. Sequences of two or more consecutive turns were defined as clause construction communication cycles (C4). Each C4 was focused on co-construction of a grammatically well-formed clause. During each C4, the adult typically recasted and prompted the participant within a sequence of turns. Figure 1 depicts an example of a C4 producing the clause, “*I like cartoon.*”

Coding clause structure.—Once all clause constructions were identified, the structure of each was coded according to its linguistic constituents (SVO) and additional phrase-

internal elements, such as verbal or nominal inflections, articles, and prepositions (see full list of glosses and abbreviations in the Supplementary Material, Table A1). For example, Participant C used an SVO: “*I like cartoon*” (Sbj + V + Obj) while Participant C, Observation 6, used possessive, a subject consisting of two nouns and a connective, an inflected copula, and a copula complement: “*My dad and mom were happy*” [(Poss)Sbj [N + and + N] + (Inf)Cop + CopCom]. Moreover, the grammatical acceptability of each clause was noted. When errors occurred, the target meaning and types of grammatical errors were then identified (see Examples 1a, 1b, 2a, and 3a, Results).

Coding linguistic complexity.—The measurement of syntactic complexity in the current study was developed based on instruments such as Developmental Sentence Scoring (Lee & Canter, 1971), which provides a numerical index representing overall complexity, and the Index of Productive Syntax (Scarborough, 1990), which indexes various commonly assessed linguistic constructs. Specifically, a complexity score for each construction, (regardless of whether or not it was judged as grammatically correct), was determined as a metric of linguistic complexity found in children with typical development (described in Table 2). Each linguistic component of each clause received one or two points depending on its added complexity. That is, more points were scored for reflecting complexity closer to the language development and linguistic structure of children with typical development. For example, the addition of a subject or modal verb added a single point to the phrasal complexity; use of a preposition, article, or interclausal connective added two points because these more arbitrary language-specific elements express more complex relations and are typically acquired later (Bloom et al., 1980; Brown, 1973; Clark, 2016; Diessel, 2004).

Moreover, based on Brown’s (1973) description of the emergence of 14 grammatical morphemes over five development stages (from age 1;0 to 3;11), two points were allocated to specific grammatical morphemes that emerged in Stage 5, such as the use of articles. The MLU in morphemes (MLUm) of the total number of clause constructions produced by each participant was calculated using SALT® software, and the MLU score was matched to the equivalent developmental stage (Miller et al., 2012).

It was also important to first identify the core structure of the clause and then assign a complexity score. For example, the clause “*Prince Prince is handsome*” matched the structure: Sbj + Cop + CopCom and received three points, even though the length of the clause was four units.

Quantifying adult prompts in C4.—The intensity of adult prompts was examined two ways. First, the overall percentage of clauses in the corpus that were constructed during one-turn sequences (autonomously constructed) versus the percentage of clauses constructed in multiturn sequences (co-constructed) was calculated. Then, the number of turns within each clearly delineated C4 sequence was calculated. For example, the intensity of adult prompts in the C4 of the clause, “*I like cartoon*” (Figure 1), was a three-turn sequence. A correlation between the complexity of the target clauses and the number of turns in the C4 was conducted for all four participants.

The lead and second author worked together to code all transcripts and resolve disagreements until they achieved consensus. Discrepancies occurred mainly in identifying the number of turns in the C4. Once the target clauses were identified, analysis was straightforward for linguistic elements and complexity scores were based on clear tabular scoring. Moreover, the linguistic elements and complexity scores were analyzed by the first and the second authors independently. Together, they coded Participant C's transcripts to establish the coding system and then independently coded the transcripts of Participants A, B, and D. The second author, a linguistics expert, reviewed and revised these analyses. The first author then revised and corrected errors detected by the second author.

Results

The corpus yielded 300 clauses (61 prestored and 239 clause constructions). Table 3 summarizes the total number of clauses, including prestored clauses and clause constructions (co-constructed and autonomously constructed), and MLUm each participant produced during observations, and their equivalent developmental stage based on Brown's (1973) stages. Participant A produced the most clauses (129), followed by Participants D (88), B (45), and C (38). However, based on the researchers' interest in tracking changes in clause formation during the interaction, prestored clauses were excluded and only clauses constructed during the interaction were analyzed. Thus, the clause counts were reduced by 12 (9%) for Participant A, one (2%) for Participant B, five (13%) for Participant C, and 43 (49%) for Participant D. Participant A produced the highest number of clause constructions during the interaction (117). Participants B and D produced a similar number (44 and 45, respectively), and Participant C produced the fewest (33). Participants A and C had an average MLUm of 4.99 and 4.85, respectively, placing them in Brown's Stage 5+. Participants B and D had an average MLUm of 3.36 and 3.3, respectively (Brown's Stage 4). For all participants, Stages 4 and 5 were at least three developmental stages higher than that calculated in the first observations before the language intervention. These higher MLUm scores reflect only the level of the identified clause constructions (co-constructed and autonomously constructed) over the period of 10 months and excluded utterances that were produced during the C4 to form the target clause. For example, the co-constructed clause, "*I like cartoon*," was coded for the MLU score, but the utterances, "*I like*" and "*cartoon*," produced during the C4 (Figure 1) were excluded.

Changes in frequency and complexity

Table 4 lists the number of clause constructions produced in each observation across participants and shows that the number increased over time for Participants A, C, and D. In Participant B's data, the number of clauses in Observation 1 was higher (7) and increased only by one in Observations 5 and 8. Importantly, the number of clauses included all clause types, even simple clauses with just a verb (e.g., *play*). To capture syntactic differences between the types of clause productions, each clause was assigned a syntactic complexity score (Table 2). In Figure 2, the highest complexity score from each observation was plotted, illustrating how grammatical complexity increased over time for all participants. The Supplementary Material includes a list of clause constructions, structures, complexity cores, and adult interaction levels for each participant.

Types of clause construction

In the first two observations, all participants produced simple SVO clause constructions. They gradually increased clause complexity (Figure 2) by adding phrase-internal elements such as adjectives, pronouns, connectives, negation, and quantifiers. The developmental pattern of personal pronouns was similar across participants and followed the pattern observed of children with typical development described in Brown's (1973) stages, wherein the pronoun *I* emerges before *you*, *she*, *we*, or *they*. The sections that follow provide examples of how each participant produced a basic SVO clause structure early in the intervention and a complex structure that emerged later, illustrating increasing structural complexity, and the emergence of personal pronouns.

In Observation 1, Participant A produced a structure that received a complexity score of 6 (Example 1a), and in Observation 7, a structure that received complexity score of 17 (Example 1b). The first-person singular *I* emerged in Observation 1, whereas the personal pronouns *you* and *she* emerged in Observations 2 and 4, respectively.

(1a) "I go with Aunt Mary house"

Paraphrased as "I go to Aunt Mary's house"

Sbj + V + Prep + (Poss)Obj [participant did not use the correct preposition and the possessive marker 's]

(1b) "I to go San _Francisco to see dad sister grandma party birthday on May Sunday 10"

Paraphrased as: "I go to San Francisco to see dad's sister at grandma's birthday party on March Sunday 10 [participant used wrong word order and did not use the possessive marker 's and the preposition at].

Sbj + (Prep) + V + Obj/Adv + (Inf)V + (Poss)Obj + (Poss)Adv [N + N] + (Prep) Adv [N + N + No.]

In Observation 1, Participant B produced a structure that received a complexity score of 4 (Example 2a); in Observation 5, he constructed a structure with a complexity score of 10 (Example 2b). The personal pronoun *I* was first produced in Observation 1, and *we* emerged only in Observation 5.

(2a) "I me read comic book"

Paraphrased as, "I read comic book." [Participant mistakenly clicked *me* when he looked for the pronoun *I*.]

Sbj + V + Obj [N + N]

(2b) "I want to go to the movies"

Sbj + (Mod)(Inf)V + (Prep)(Art)(Inf)Obj

In Observation 2, Participant C produced a basic structure that received a complexity score of 4 (Example 3a), and in Observation 4, a structure with a complexity score of 13 (Example

3b). The pronoun *I* was first produced in Observation 2, and *he* and *they* emerged in Observation 3.

(3a). “I want bed sleep”

Paraphrased as, “I want to sleep in bed” or “I want bed” [indicating participant was tired a turn before]

Sbj + (Mod)V + Obj,

(3b) “I am going to the beach with my family”

Sbj + (Inf) (Inf) V + (Prep) (Art) Obj + (Prep) (Poss) Obj

In Observation 2, Participant D constructed a simple structure with a complexity score of 3 (Example 4a), and in Observation 4, a structure that received a complexity score of 7 (Example 4b). The first-person singular *I* emerged in Observation 2, whereas the personal pronouns *we* emerged in Observation 3, *he* in Observation 6, *she* in Observation 7, and *they* in Observation 8.

(4a) “I like car”

Sbj + V + Obj

(4b) “Went with my mom post office”

Paraphrased as, “I went with my mom to the post office” [missing the preposition and article].

(Inf) V + (Prep) (Poss) Obj + Adv

Grammaticality and co-construction

All participants’ clause constructions were coded for grammaticality (correct word order, appropriate verb inflections, no missing articles, prepositions, connectives, and use of context-appropriate pronouns) and the number of turns to construct the clause. The researchers predicted that the percentage of grammatical clauses would positively correlate with the percentage of co-construction. In other words, constructions supported by a conversation partner were more likely to be grammatical. Table 5 details the percentages of grammatical and ungrammatical clauses and the percentage constructed in one turn versus multiple turns. The intensity of adult prompts in the participant corpus is the percentage of the clauses co-constructed, constructed in more than one turn, and prompted during C4. As illustrated in Figure 3, Participant A had the lowest percentage of grammatically correct (46%) and co-constructed (30%) clauses, followed by Participant D (62% and 51%, respectively). Participants B and C had the highest percentage of grammatically correct (93% and 79%, respectively) and of co-constructed (77% and 100%, respectively) clauses. These data display a positive correlation between co-construction and grammatically correct clauses. Specifically, as the percentage of co-constructed clauses and adult prompts increased, the percentages of grammatically correct clauses also increased.

A correlation coefficient was computed to assess the relationship between the number of turns in the C4 and the complexity score. Across all participants ($N = 157$ rows of data), the

correlation was positive and statistically significant ($r = .3, p < .05$). Although the magnitude of the correlations was modest for each participant, a positive correlation was statistically significant for three participants: Participant A ($n = 35, r = .2, p = .26$); Participant B ($n = 44, r = .6, p < .05$); Participant C ($n = 33, r = .8, p < .05$); Participant D ($n = 45, r = .3, p < .05$). In sum, there was evidence for positive correlation between the complexity score and amount of adult support. Because Participant A had a significantly higher number of clause constructions ($n = 117$) than Participants B, C, or D ($n = 44, 33$, and 45 , respectively), only clauses co-constructed in more than one turn ($n = 35$) were included in the analysis of her data; clauses autonomously constructed in one turn ($n = 82$) were excluded from this analysis.

The types of grammatical errors across participants are summarized in Table A6 (Supplementary Material). All participants produced errors in their use of inflection and articles; Participants A, C, and D in word order and use of prepositions; and Participants A and D in use of connectives. Participant A had the highest number of grammatical errors (115). Therefore, her unique errors (e.g., not using copula, auxiliary, modals, or possessives and incorrect use of adverbs and pronouns) that were produced in low frequency were grouped as “other.”

Discussion

The findings of this study indicate that for all participants, the complexity of clause construction increased over time, as measured by the syntactic complexity score developed in this study. Moreover, the average MLUm of the analyzed clause construction in the participant corpus was higher by at least three developmental stages (Brown, 1973) than the stage calculated in the first observation before the language intervention. From the beginning, all participants produced simple SVO clause constructions and gradually increased clause complexity by adding internal-phrase elements such as adjectives, pronouns, connective, negation, and quantifiers and increasing the number of elements in the utterances. All participants first produced the personal pronoun *I* before other personal pronouns (*you, she, we, or they*). Similarly, the verbal inflection production of these participants also followed Brown’s stages, as shown in the emergence of the present simple third-person after the present progressive (*ing*) and the past (*ed*). For more details about verbal inflection, see Savaldi-Harussi and Soto (2018). Across participants, constructions supported by the adult during the C4 were more likely to be grammatical and, as the clause complexity increased, more adult support (number of turns) was needed to construct the clause.

These general patterns of increasing the number of clauses, adding complexity over time, and producing specific structures in specific order (pronouns, verbal inflection) follow the complexity path described in children with typical development (Brown, 1973; Clark, 2016). Four hypotheses might explain these patterns. First, these findings may relate to input the participants received during the intervention and generalization sessions (Romberg & Saffran, 2010; Yurovsky et al., 2012). Although the requirement was not explicitly stated in the intervention protocol, perhaps the linguistic structures that the trained clinicians targeted during the sessions followed a developmental trajectory. Moreover, the familiar adults

changed their types of scaffolding input during the generalization sessions as the participants improved their grammatical skills. Over time, the familiar adults increased the use of recasts (reformulating the children's previous utterances) and decreased the use of yes/no questions for clarification (Savaldi-Harussi & Soto, 2018). Second, the findings could relate to vocabulary growth and its strong correlation to grammatical complexity and the emergence of specific grammatical structures (Dixon & Marchman, 2007; Goodman & Bates, 2013). Over the 10-month period, the participants increased their lexicon and, specifically, their use of different verb categories (Savaldi-Harussi & Soto, 2018), which boosted the emergence of different clause structures and verbal inflections. Third, these results could relate to intrinsic (e.g., motor and cognitive skills) factors. Over the intervention period, participants improved their motor planning in locating the grammatical features in their communication device, as well as their ability to express less salient but more complex grammatical features (e.g., locating the icon for the symbol *bridge* to select prepositions). Fourth, these patterns support Loncke's (2014) suggestion that, when given adequate assistance, children who use AAC will follow similar channels to process and exchange information as would children with typical development.

The types of errors that occurred in formulating the different clause structures could imply more complex structure types or illuminate peculiarities of communicating using aided AAC; the latter would indicate that the errors were influenced by the graphic-symbol modality (Blockberger & Johnston, 2003; Mano-Lerman, 2017; Smith & Grove, 2003; Sutton et al., 2002; von Tetzchner & Martinsen, 1996). The modality-specific hypothesis (Sutton et al., 2002; Trudeau et al., 2007) explains that children who use the graphic-symbol modality tend to omit verbal inflection, even when these grammatical markers are available in the device, because the inefficient communication process involving multiple steps to select the target morpheme slows their communication speed. In many cases, communication partners can understand the message without spending time on this process.

The adult-child pairs in this study used techniques that are unique to aided communication, such as preprogrammed phrases, to overcome cognitive, physical, and linguistic barriers. Although these phrases were excluded from the linguistic analysis, it is important to note that for many children who use aided AAC, the desire to communicate quickly and efficiently may result in a preference for strategies that deliver short messages without grammatical markers or that use preprogrammed phrases (Nelson, 1992). However, only Participant D used this strategy dominantly in her corpus. The use of prestored clauses can inform judgments about the participants' pragmatic competence in conversation. For example, children who use aided AAC may use the same phrase they used in previous turns for various reasons. Such use could result from an operational issue (e.g., if the participant had not properly cleared the device after last use) or for pragmatic reasons, such as choosing to repeat a previously constructed message to reply quickly.

The communication partner has a crucial role in supporting language growth in children who use aided AAC. As expected, participants with high percentages of co-constructed clauses also had high percentages of grammatically correct clauses as a result of the adult support (Savaldi-Harussi & Soto, 2018). Moreover, for three participants, the number of turns in each C4 increased as the clause complexity increased. The time employed during each C4

was not analyzed. However, the number of turns demonstrated that constructing grammatically correct complex utterances takes time. For example, the clause Participant C constructed across 19 turn sequences, *“I am going to the beach with my family,”* received a complexity score of 13. These findings also highlight the conflict between conveying efficient messages in a short time or complex structures in a longer time.

Finally, on the issue of measuring grammatical complexity of clauses produced by children who use aided AAC, the MLUm of clause constructions may better inform clinicians of the linguistic competence of children who use aided AAC than would the MLUm of whole utterances in the transcripts. Considering the characteristics of aided communication, assessment of changes in the syntactic complexity of the utterances of children who use AAC should use language samples that include the target clauses produced during C4 (as explained in the Results section). Such samples would provide valuable information about a child’s syntactic competency and reduce operational (mis-hits, repetitions), pragmatic, and modality influences on the MLU.

In relation to children with typical development, Klee and Fitzgerald (1985) considered which utterances should be included in a language sample to reliably assess expressive language. Those authors suggested using mean syntactic length, which excludes single-morpheme responses from the language sample, instead of the general MLUm, which was found unreliable in later developmental stages. Kovacs and Hill (2017) adapted the mean syntactic length method to assess expressive language of children who use aided AAC by analyzing only “utterances with two or more morphemes and two or more language events” (p. 5). Their main challenges in using MLUm in language samples of children who use aided AAC include the difficulty of collecting representative data, defining utterance boundaries, and, importantly, differentiating between contextualized and decontextualized language samples. Discussion of the reliability of general MLUm measurements (Brown, 1973) is beyond the scope of this paper; however, to better assess the syntactic complexity of the clauses of children who use aided AAC, including a measure of complexity such as developed for this study is worth considering. For example, this measure helped solve instances in which participants listed or repeated the same words in the clause and thus increased the length of their utterances. It is important to first identify the core structure of the clause and then assign a complexity score.

Clinical implications

These findings illuminate considerations for grammar interventions with children who use speech-generating devices. They also provide robust evidence for following the linguistic complexity found in children with typical development when targeting grammatical markers during the interventions. Moreover, focusing on increasing the lexicon—specifically the use of verbs, which are the core of a clause—may increase the use of clause structures and the formulation of complex clause structures by adding phrase-internal elements. Constructing grammatically correct clauses that include inflections, articles, and prepositions requires a systematic intervention due to the characteristics of the graphic-symbol modality and aided communication. Intensive training is required to locate these features in a communication device and to learn to use them to formulate grammatically correct clauses. Although adults

play important roles in supporting a child's language development, it is also important to acknowledge the compensation strategies these participants used to navigate cognitive, physical, and linguistic barriers during interactions (e.g., Soto, 1999; Sutton et al., 2002).

Limitations and future directions

These findings should be interpreted according to the study's limitations. As with many corpus studies in child language that include observational data on child development, the sample size in our study was relatively small. Reliable sample sizes should be based on at least 50 free utterances (utterances with at least a noun and verb in subject-predicate relationship, including all subordinations and excluding conjunctions), in which conjunctions yield separate utterances because they have complete verb predicates (Lee, 1974; Lee & Canter, 1971). The sample size in this study did not meet this criterion. Over the 10-month period, Participants B, C, and D produced fewer than 50 clause constructions (co-constructed and/or autonomously constructed) that included a complete verb predicate without excluding conjunctions. The developmental pattern of clause construction should be further explored with a larger number of participants and reliable sample sizes. In addition, the new procedure suggested here for assessing clause construction complexity, that is, identifying the target clause within a C4 and assigning it a complexity score, requires further examination with more participants to determine its reliability as a measure. Future research may also examine the relationship between the types of adult prompts during C4 and the production of specific linguistic features to understand better which prompts enhance production of specific grammatical clauses.

Conclusion

This study's findings indicate that, with adequate assistance, individuals with motor speech disorders who use an SGD can construct grammatically correct clauses with various linguistic elements such as articles, prepositions, verbs, and modals. Clauses constructed in a co-constructed interaction of two or more sequences are more likely to be grammatically correct. As the clause structure becomes more complex, there is a need for more support (i.e., more turns) from communication partners during interactions. The developmental path of growth in clause complexity over the 10-month period of this study followed an order observed in children with typical development (i.e., children first produce the basic SVO clause form and then add inflection and grammatical morphemes to the construction). In sum, this study illuminates the linguistic practices of children with motor speech disorders as they shift from uttering single verbs to constructing well-formed clauses.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Participant	Adult
C: "I like."	A: <i>Who? Who's going to the park? What about the park? You need to add more.</i>
C: "Cartoon."	A: <i>I like. I'd like to go to the park for your birthday? You're okay. Good.</i>
C: "I like cartoon."	A: <i>Are you moving on with your topic? Yeah? So, can you say that whole thing?</i>

Figure 1.
Example of clause construction communication cycle (C4).

Figure 2.
Most complex clause construction in each observation. Figure shows an increase in complexity over time.

Figure 3. Percentages of grammaticality correct clauses and co-constructed clauses (adult prompts) across children. As the percentage of the adult prompts increased, the percentage of grammatically correct clauses also increased.

Table 1

Participants' Demographic Characteristics

Participant	Age	Speech disorder	Mobility	SGD ^a	SGD access	Language spoken at home	Receptive vocabulary age equivalent (percentile)	Morphological judgment age equivalent (percentile)	Speech intelligibility rating
A	9;5	Dysarthria secondary to Pfeiffer syndrome	Wheelchair user	DynaVox DV 4 with Gateway Modified 45, 60	Finger pointing	English, Spanish	8;6 ^b (37)	6;6 ^b (9)	0% (nonverbal)
B	13;7	Dysarthria secondary to cerebral palsy	Wheelchair user	Vantage Light with Unity 84	Joystick	English, Spanish	8;11 ^c (5)	< 8 ^d (n/a)	20% (minimally verbal)
C	13;3	Dysarthria secondary to cerebral palsy	Wheelchair user	Vantage Light with Unity 60	Finger pointing	English, Arabic	9;6 ^c (7)	< 8 ^d (n/a)	0% (nonverbal)
D	12;1	Severe verbal apraxia, etiology unspecified	Ambulant	Vantage Light with Unity 84	Finger pointing	English, Spanish	9;5 ^c (12)	< 8 ^d (n/a)	40%

Note. Participants aged 9;5 to 13;7 (years;months). Participants A and D were female; B and C were male. All participants' expressive language had mean length of utterance (MLU) of 1–2, mostly nouns and adjectives.

^a Gateway™ and Unity™ are language-based vocabulary organization systems that include core vocabulary words (i.e., most frequently used words), allowing for the creation of spontaneous and novel messages, and grammatical markers, allowing for grammaticalization of the utterance.

^b Obtained from test of auditory comprehension of language-3 (Carrow-Woolfolk, 1999).

^c Obtained from Peabody picture vocabulary test-4 (Dunn & Dunn, 2012).

^d Obtained from test of language development-I:4 (Newcomer & Hammill, 2008); percentile not applicable (n.a.).

Table 2

Quantifying complexity

Point allocation	Structure type	Example
+1	Verbal argument (subject, object, complement)	Nouns
+1	Verb (regular, copula, modal)	<i>Come, am, want to</i>
+1	Inflection (nominal, verbal)	Plural <i>-s</i> , present <i>-s</i> , past <i>-ed</i> , progressive <i>-ing</i>
+1	Modifiers (adjective, quantifier, possessive, another noun, etc.)	<i>Big car, one car, my car, cat's</i>
+1	Negation	<i>No, not</i>
+2	Article	<i>A, an, the</i>
+2	Preposition	<i>In, on, around, with</i>
+2	Inter-clausal connective	<i>And, when, because</i>

Table 3Frequency, MLU_m, and developmental level of clause constructions

Participant	All clauses	Prestored clauses	Clause constructions	MLU _m ^a	Brown's ^b stage
A	129	12 (9%)	117	4.99	5+
B	45	1 (2%)	44	3.36	4
C	38	5 (13%)	33	4.85	5+
D	88	43 (49%)	45	3.30	4
Total	300	61	239		

Note.

^aMLU_m = mean length of utterance in morphemes;^bBrown (1973).

Table 4

Number of clause constructions produced over Time

Observation	Participant A	Participant B	Participant C	Participant D
1	4	7	0	1
2	8	4	1	4
3	14	6	7	5
4	17	5	9	7
5	13	6	5	8
6	23	8	11	7
7	15	8	-	5
8	23	-	-	8
Total	117	44	33	45

Table 5

Grammaticality and Co-Construction

Participant	Clause constructions produced	% (number) grammatical	% (number) ungrammatical	% (number) constructed in one turn/ autonomously	% (number) co-constructed or adult prompts
A	117	46 (54)	54 (63)	70 (82)	30 (35)
B	44	93 (41)	7 (3)	22 (10)	77 (34)
C	33	79 (26)	21 (7)	0	100 (33)
D	45	62 (28)	38 (17)	49 (22)	51 (23)