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Strategies in Construction and Interpretation of Graphic-Symbol Sequences by Individuals who use AAC Systems

NATACHA TRUDEAU[a]*, ANN SUTTON[a], JILL P. MORFORD[b], PATRICIA CÔTÉ-GIROUX[a], ANNE-MARIE PAUZÉ[c] and VÉRONIQUE VALLÉE[d]

[a]*Université de Montréal and CHU Sainte-Justine,* [b]*NSF Science of Learning Center on Visual Language & Visual Learning (VL2) and University of New Mexico,* [c]*Hôpital du Sacré-Cœur de Montréal and Hôpital Juif de réadaptation, and* [d]*Commission Scolaire des Grandes-Seigneuries, Quebec, Canada*

Given the frequent use of graphic symbols in augmentative and alternative communication (AAC) systems, some individuals who use AAC may have greater familiarity with constructing graphic-symbol sequences than do speaking individuals without disabilities. Whether this increased familiarity has an impact on the interpretation of such sequences or on the relationship between construction and interpretation is fundamental to our understanding of the mechanisms underlying communication using graphic symbols. In this study, individuals who use graphic-symbol AAC systems were asked to construct and interpret graphic-symbol sequences representing the same target content (simple and complex propositions). The majority of participants used stable response patterns on both tasks; a minority were inconsistent on both tasks. Asymmetrical patterns (stable on one task but not the other) were rare, suggesting that neither channel (construction or interpretation) preceded the other, in contrast to earlier findings with participants without disabilities (i.e., novice users of graphic symbols). Furthermore, there were differences between stable and less stable responders on measures of syntactic comprehension and cognitive level but not on chronological age, receptive vocabulary, or AAC system characteristics and length of use.

Keywords: Augmentative and alternative communication; Graphic-symbol sequences; Production; Comprehension; Syntax

INTRODUCTION

Individuals who use augmentative and alternative communication (AAC) systems typically rely on graphic symbols for their expressive communication, but use spoken language for receptive communication. Past research involving individuals who use AAC has reflected this unique input-output relationship by investigating either (a) the construction of utterances using graphic symbols or (b) the comprehension of spoken utterances[1] (see Binger & Light, 2008, for a review). As a consequence, our understanding of graphic-symbol utterance construction is much more detailed than our understanding of graphic-symbol utterance interpretation. In addition, comparisons of utterance construction and interpretation in the same set of participants are rare. A few studies have examined both graphic-symbol utterance construction and *spoken* utterance comprehension, but the modality difference in these tasks makes comparison difficult. These studies (Bruno & Trembath, 2006; Lund & Light, 2001; Smith & Grove, 2003; Sutton & Gallagher, 1995) may allow broad comparisons between the two modalities, but specific observations regarding the correspondence between expressive (graphic symbols) and receptive (speech) skills cannot be drawn.

*Corresponding author. Centre de recherche du CRME, 5200 Bélanger est, Montréal, Qc, Canada, H1T 1C9. Tel: +1 514 343 6111 ext. 1-1643. Fax: +1 514 343 2115. E-mail: Natacha.trudeau@umontreal.ca

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Although it is important to investigate production and comprehension in the modalities that individuals needing graphic-symbol AAC systems experience, further insight into processes underlying graphic-symbol communication can be gained by studying construction and interpretation *within* the graphic symbol modality. In the current study, graphic-symbol sequences were constructed and interpreted by individuals who use AAC.

The use of graphic symbols in intervention programs for individuals with severe intellectual disabilities (e.g., Barton, Sevcik, & Romski, 2006; Ganz, Sigafoos, Simpson, & Cook, 2008) suggests that graphic symbols are easier to produce than are spoken words. However, the transition from single-symbol to multi-symbol utterances is recognized as a difficult step for children who use graphic-symbol AAC systems (Paul, 1998), at least when no specific support is provided, and is thus a relevant intervention target (e.g., Binger, Kent-Walsh, Berens, Del Campo, & Rivera, 2008; Binger & Light, 2007). Studies involving novice graphic-symbol users (i.e., participants without disabilities) and targeting specific sentence structures have found that graphic-symbol sequences may differ from spoken word order (Sutton, Gallagher, Morford, & Shahnaz, 2000), and that the correspondence drawn between spoken and graphic-symbol utterances may vary across individuals. For instance, young children (3–4 years of age) showed intra-individual variation by constructing a variety of graphic-symbol sequences for simple sentences that they produced orally in a consistent manner (Sutton, Trudeau, Morford, Rios, & Poirier, 2010). In other studies, a stable response pattern was observed within but not across participants, revealing inter-individual variation as well. Trudeau, Sutton, Dagenais, de Broeck, and Morford (2007) found that French-speaking participants (school-aged through adult) constructed stable response patterns (intra-individual stability) that differed across the participants (inter-individual variability) to convey the same spoken sentence structure (e.g., *GIRL HAT PUSH CLOWN* and *GIRL PUSH CLOWN HAT* for "The girl who pushes the clown wears a hat").

Developmental level seems to have an important role in the ability to construct sequences of graphic symbols. When asked to construct sequences of graphic symbols corresponding to simple (SVO) sentences that they produced orally, preschool-aged children selected the correct symbols most of the time, but did not sequence them to adhere to the spoken word order (Sutton et al., 2010). School-aged children, in contrast, were able to construct graphic-symbol sequences for simple structures, but not all participants could construct complex sentence structures (Trudeau et al., 2007). Teenagers and adults responded consistently and correctly on both simple and complex structures, regardless of the number of photos presented. This evolution could be linked to several factors, including increased language skills, improved metalinguistic skills, general cognitive development, or experience with the graphic modality through literacy.

Interpretation of sequences of graphic symbols by novice users exhibits the same characteristics observed in utterance construction. Trudeau, Morford, and Sutton (2010) explored interpretations of both three- and four-symbol sequences across four age groups of participants (preschool, school-aged, teenagers, adults). In the youngest group, almost a quarter of the participants did not choose a consistent interpretation for three-symbol sequences and 77% were inconsistent for four-symbol sequences. In contrast, intra-individual variability was very low in all other groups for both three- and four-symbol sequences, with a majority of participants choosing a consistent interpretation for each type of sequence presented. Inter-individual variability was also observed in this study, with specific interpretations of some sequences varying across participants. Furthermore, Sutton, Gallagher, Morford, and Shahnaz (2002) found that a sequence of symbols was interpreted differently depending on the surrounding symbol context.

When construction and interpretation of graphic-symbol sequences are compared within the same novice-user participants, there is some indication that the ability to interpret may precede the ability to construct a sequence (Sutton et al., 2010; Trudeau et al., 2007, in press). In these studies, some of the participants not yet consistently using the target in construction nevertheless consistently interpreted the corresponding sequence of graphic symbols. In summary, for speaking individuals without disabilities, consistency and accuracy increase across development, and construction and interpretation of graphic-symbol sequences eventually become coordinated.

The atypical expressive language experience of individuals who use AAC is frequently viewed as a limitation or potential restricting factor in language development (e.g., Blockberger & Johnston, 2001; Blockberger & Sutton, 2003). However, individuals who use graphic-symbol AAC systems for communication have greater familiarity with the use of graphic symbols for constructing sequences. Whether this has an impact on either the interpretation of such sequences or the relationship between construction and interpretation is an open question. For speaking individuals who are novice users of graphic symbols, it could be argued that knowledge of spoken language syntax mediates these processes, their graphic-symbol sequences increasingly following the syntax of the spoken language across development (Sutton et al., 2010; Trudeau et al., 2007). In addition, the relationship between construction and interpretation within the graphic modality mirrors their relationship within the oral modality; namely, that comprehension generally precedes production. Given the extent of differences in expressive experiences and the unique asymmetry between input and output, a somewhat different relationship may exist between (a) oral and graphic-symbol skills, and (b) construction and interpretation of graphic-symbol utterances by individuals who use graphic symbols on a daily basis.

One study explored both construction and interpretation using graphic symbols in participants who use AAC (Sutton, Morford, & Gallagher, 2004). When interpreting sequences that the participants themselves had constructed, the meaning they attributed did not necessarily correspond to the meaning of the original target. This suggests that the interpretation assigned to sequences may not necessarily adhere to what would be expected, based on either the corresponding spoken word order or the individual's own constructions.

Exploration of construction and interpretation within the graphic-symbol modality addresses fundamental questions regarding the mechanisms underlying communication using graphic symbols. Experience could lead to reduced intra-individual variability (i.e., increased stability of responding) when compared with novice users. Individual experienced users would then be expected to have stable ways of responding (strategies) that may or may not follow the word order of the spoken language. If users attempt to adhere to the grammar of the spoken language, one would predict similarities in patterns of construction and interpretation of graphic-symbol sequences across novice and experienced users because they would be trying to match the same target (i.e., oral) utterance. However, if experienced users follow a "grammar" that is inherent to graphic symbols, more variability between novice and experienced users would be expected even though members of each group may demonstrate consistent strategies. Alternatively, experienced users of graphic symbols may try to minimize effort and maximize efficiency with little regard for the structures of the spoken language that they understand. In this case, variability across individual experienced users and deviations from spoken language structures would be likely when another more efficient way of transmitting the message can be found.

The purposes of this study were to explore construction and interpretation of graphic-symbol sequences by individuals who use graphic symbols for communication and to examine the influence of individual characteristics on performance. Based on the literature, it was expected that (a) individuals who use AAC would use consistent strategies when interpreting and constructing graphic-symbol sequences; (b) performance on interpretation would be as good as or better than performance on construction; (c) individual differences would occur in the use of strategies and the choice of specific strategies; and (d) some of the individual variability could be explained by factors related to personal characteristics or AAC experience.

METHOD

Participants

Twenty-seven participants met the following inclusion criteria: (a) have French as the primary language; (b) present with severe speech problems precluding the use of speech; (c) use a graphic-symbol-based AAC system with a minimum of 30 symbols at the time of the study; and (d) have been using such a system for at least 6 months. No criterion was imposed regarding duration of use of the participant's current AAC system, because the study involved experimental tasks performed on a system that was not the participants' own. Thus, operational competence on their current system was not deemed to be as important as their overall level of AAC experience. Participants were not included if their AAC system was based only on the alphabet or semantic compaction (Baker, 1982), if their primary diagnosis was specific language impairment or autism spectrum disorder, or if the speech problem was acquired after initial oral language development (i.e., after age 2). Age, language level, and cognitive skills were documented in order to explore their impact, although no criteria were imposed. For receptive language skills, the Épreuve de compréhension de Carrow-Woolfolk (ÉCCW) (Ska, 1995), a French adaptation of the Test of Auditory Language Comprehension-revised (TACL-R; Carrow-Woolfolk, 1985) and the Échelle de vocabulaire en images Peabody (ÉVIP) (Dunn, Thériault-Whalen, & Dunn, 1993) were used. Cognitive skills were assessed using the Columbia Mental Maturity Scale (CMMS) (Burgemeister, Blum, & Lorge, 1972) or the Test of Nonverbal Intelligence (TONI) (Brown, Sherbenou, & Johnsen, 1997). A socio-demographic questionnaire was completed by each participant or someone familiar with him or her (e.g., parent, caregiver, teacher).

After ethics approval was obtained, participants were recruited through rehabilitation centers and schools, where staff identified clients meeting the selection criteria, and sought permission before allowing the research team to approach potential participants. Adult participants gave consent on their own, while parents provided written informed consent for participants under 18 years of age. Participants provided assent at the beginning of each session.

Of the 27 participants recruited, 22 completed all tasks of the experimental protocol. These 22 participants constitute the sample of the current study (see Table 1). There were 9 females and 13 males whose ages ranged from 8–49 years (mean = 28, *SD* = 13.8). Most participants (*n* = 16) were monolingual French-speakers; five reported some level of knowledge of a second language (mostly English); and one reported knowledge of French, English, and Portuguese. There was wide variation within the group on all characteristics. Concerning education level, some of the oldest participants had received little if any formal schooling, and younger participants were still in school, although not always following the mainstream curriculum. Several AAC devices were used by the group, most of them including voice output (15/22). Some participants had access to more than 1000 symbols on their device, while others mostly used one display containing fewer than 100 symbols. The types of symbols used varied, with the most frequent being Parlerpictos (Centre québécois de la communication non orale (CQCNO), 2002), Blissymbols (Hehner, 1980), Picture Communication Symbols (PCS) (Johnson, 1994), and Minspeak icons (Baker, 1982), used as single symbols. Experience with AAC in general (from 6 months to 41 years) and with the current AAC system (from one day to 40 years) also reflected the heterogeneity of this population. The most common diagnosis of the participants was cerebral palsy (20/22).

General Procedures

Each participant was seen by two experimenters in a quiet location. Length (15–60 min) and number (2–18) of sessions depended on scheduling constraints, and fatigue of the participant. One experimenter interacted with the participant and presented the materials. The second experimenter recorded responses and ensured that the session ran smoothly. Language and IQ tests were administered first, followed by two experimental tasks: the Construction task and the Interpretation task. Total testing time also included another task (an adaptation of a pragmatic task) and an additional condition in the Construction task (described below) that were not used as part of the data for the current study.

Construction Task

This task is the same as the one used in Trudeau et al. (2007). Only one of the two conditions (called ''contrast condition'' in Trudeau et al.) is part of the current study.

Stimuli

Simple and complex spoken sentences were used. Simple sentences were noun-verb-noun (N1 V N2) single propositions such as ''The clown pushes the girl'' (N1 = clown V = push N2 = girl). Eight examples of simple propositions were created by combining four agent-patient pairs (girl-clown, clown-girl, boy-clown, clown-boy) with two reversible actions (push, pull). For the complex sentences, an attribute (hat or scarf) was added to one of the characters (agent or patient) in the simple propositions. Two types of complex sentences were used: subject relative clauses (SS) (''The clown who pushes the girl wears a scarf'') or object relative clauses (OS) (''The clown pushes the girl who wears a scarf''). Only the placement of the pronoun 'who' distinguishes these two sentence types; thus, they had the same ordering of content words, namely, N1 V N2 W A (W = verb ''wear''; A = attribute – scarf or hat). Combining the different agents, actions, patients, and attributes resulted in 32 complex propositions (16 SS, 16 OS). Each participant received 8 simple sentences and 16 complex (8 OS and 8 SS) sentences. These sentences were divided into two blocks, one containing the simple sentences, and the other containing the complex sentences, with SS and OS structures randomly ordered.

Materials

A number of 10.1 cm × 15.2 cm photographs depicted the event described in each of the stimuli. All photographs included four characters, two involved in the action, and two bystanders. The bystanders were included to make the mention of the attribute relevant in the complex sentences. Photographs were arranged four per page in a binder and were identified with a number (1 to 4). For simple sentences, the four photos represented the same two characters pushing and pulling each other. For complex sentences, the four photos depicted the same two characters involved in one of the actions, and wearing one attribute (e.g., 1. Boy with scarf pushing clown; 2. Clown with scarf pushing boy;

TABLE 1 Characteristics of the Participants.

Participant	Age	Gender	Other lang.	Schooling	VOCA	Number of symbols[1]	Years using AAC[1]	Years current system	Main diagnosis[2]	Motor impairment	Access method in experiment	ÉVIP raw score	ECCW raw score
1	21:08	M	Y	Grade 9	Y	Over 140	7	2	Unknown	Moderate	Direct	81	86
2	10;06	M	N	Grade 2	Y	Over 400	Unknown	Unknown	Mixed	Severe	Direct	53	99
3	14;06	F	Y	Grade 2	Y	Unknown	3	0,5	Athetoid	Severe	Scanning	114	113
4	16;11	M	Y	SE	N	Over 140	Unknown	Unknown	Spastic	Severe	Mixed	17	50
5	15;06	M	N	SE	Y	Unknown	10	Unknown	Apraxia	Mild	Direct	57	85
6	15;09	F	N	SE	Y	Unknown	4	2	Mixed	Severe	Mixed	43	79
7	8;06	M	N	Grade 1	Y	Over 100	3	0,5	Spastic	Severe	Direct	75	108
8	28;11	F	N	None	N	Over 60	11	3	Mixed	Severe	Scanning	111	96
9	9;04	F	N	Grade 1	Y	1000	3	1	Athetoid	Moderate	Direct	35	66
10	36;01	F	Y	Grade 2	Y	Unknown	0,5	0,5	Mixed	Severe	Direct	59	94
11	37;04	M	N	Grade 12	N	Over 50	30	2	Spastic	Severe	Direct	101	110
12	36;07	M	N	Grade 12	Y	1000	14	0	Athetoid	Severe	Direct	116	114
13	41;09	M	N	Adult literacy	Y	Over 375	6	6	Unsp. CP	Mild	Direct	63	95
14	37;04	F	N	Grade 12	Y	Over 650	20	0,5	Mixed	Severe	Direct	78	108
15	14;08	M	N	SE	Y	Over 30	Unknown	Unknown	Spastic	Mild	Direct	78	102
16	41	M	N	Grade 3	N	Over 200	30	30	Mixed	Severe	Direct	132	108
17	26;09	F	Y	Unknown	Y	Over 400	10	Unknown	Spastic	Severe	Mixed	87	88
18	49;09	F	Y	None	N	Over 140	2	2	Unknown	Moderate	Direct	140	109
19	49;08	M	N	Grade 3	N	Over 700	41	40	Mixed	Moderate	Direct	61	100
20	43;04	M	N	Grade 5	N	Over 90	20	Unknown	Mixed	Severe	Direct	135	115
21	27;10	F	N	SE	Y	Over 650	7	1,5	Mixed	Moderate	Direct	34	64
22	44;11	M	N	Adult literacy	Y	Over 600	20	4	Mixed	Severe	Mixed	135	86

SE, Special education; Unsp., Unspecified; Direct, Direct selection with hand or finger, unless otherwise specified; Scanning, Partner assisted scanning; ÉVIP, Échelle de vocabulaire en images Peabody; ÉCCW, Épreuve de comprehension Carrow-Woolfolk.

[1]When Unknown, participant met inclusion criterion based on eligibility checklist, but exact value was not provided by participant or other respondent on the detailed questionnaire.

[2]Unless otherwise specified, main diagnosis refers to type of CP.

3. Boy pushing clown with scarf; and 4. Clown pushing boy with scarf). Graphic-symbol displays were created, containing the vocabulary needed to construct the target sequences (*GIRL, BOY, CLOWN, SCARF, HAT, PUSH, PULL, WEAR*). Additional symbols for commands allowed participants to modify their response (*DELETE*) and indicate when they were ready to move on to the next test item (*NEXT*). Ten colored PCS and their written labels were arranged on three different displays that allowed for different access methods (see below). The first display contained two rows of five PCS (1.9 cm × 3.8 cm) presented on a computer screen. The symbols on the top row were the characters (*CLOWN, GIRL, BOY*) and the attributes (*SCARF, HAT*), arranged from left to right. On the bottom row were the symbols for the verbs (*WEAR, PUSH, PULL*) and the commands (*NEXT, DELETE*). The second display was a copy of the first one with bigger symbols (7.6 cm × 7.6 cm) presented on a 27.9 cm × 43.1 cm board. The third display used the larger (7.6 cm × 7.6 cm) symbols, arranged around a Plexiglas frame. A PC laptop, running Écrire en symboles, 2000 (a graphic-symbol authoring software by Widgit Software, 2000) presented the symbol display and a message window concurrently. The Écrire en symboles window was divided into four areas; in the bottom right area was the symbol display described previously. The message window, where selected symbols appeared, occupied the largest area, in the top right of the screen. The top left of the screen contained arrows allowing the user to control the cursor in the message window and modify previous selections. The bottom left corner contained the digits 1 through 4, used to identify to which photo the symbol sequence was associated. The PC was used regardless of participants' access mode. When a participant used the enlarged paper display or the eye-gaze display, the experimenter entered their choices on the computer for data recording purposes. Graphic-symbol sequences could thus be constructed, displayed, and revised for each set of four photographs. They were also saved in a separate file for each participant for later analysis. Speech synthesis (IBM's ViaVoice synthesizer – "Jacques" voice) accompanied the selection of each graphic symbol, and produced the whole sequence constructed when the "Next" command was selected. Use of the speech output provided immediate feedback regarding individual symbols, reducing the risk of visual confusion in symbol selection, as well as the complete version of the symbol sequence, as is typically done in voice output AAC devices.

Training and pretesting

Training tasks included identifying individual graphic symbols, copying sequences of symbols, and describing photographs using graphic symbols. The materials used were similar to those in the experimental task, but the combinations were different (i.e., they involved a boy and a girl, rather than a boy and a clown or a girl and a clown). The training tasks were used (a) to confirm that participants understood the meaning of all relevant symbols (selecting the correct symbol on demand five consecutive times or six out of eight times, whichever came first); (b) to establish a reliable response system and select the best interface for participants; (c) to verify that participants could use the chosen type of interface successfully to copy sequences of five symbols; and (d) to practice all of the steps involved in the experimental task. Responses during the training tasks were not judged in terms of accuracy, nor were participants given feedback on the sequences constructed. The access methods used by participants varied: five used direct access through the touch screen of the computer, two used partner-assisted scanning on the touch screen, 10 used direct access on a communication board with an enlarged reproduction of the touch screen display, while the other five used mixed methods such as direct access through eye gaze or partner-assisted scanning using a Plexiglas frame. In all cases, when a direct selection was ambiguous (i.e., when the two experimenters disagreed on what was selected), a confirmation was obtained using partner-assisted scanning and yes/no responses.

Experimental task

The experimenter read the instructions aloud. The participant was asked to construct a different graphic-symbol utterance for each stimulus sentence (and its accompanying photograph), using the graphic-symbol display. For each trial, the tester read aloud the stimulus sentences printed on the back of the photographs. After hearing the four target sentences, the participant then selected symbols from the display to construct a symbol sequence for each photograph, in the order of his or her own choosing, using the numbers to identify the photograph he or she was working on. For participants who were not using direct access to the computer screen, the experimenter entered each selection onto the computer after the participant had made a choice and, when necessary confirmed it. When the participant selected *NEXT*, he or she was asked to confirm readiness to move on. Once the confirmation was obtained (or after modifications were made if the participant chose to do so), the tester turned to the page displaying the next group of photographs. Each participant received two pages of simple proposition sentences (i.e., eight sentences) and four pages of complex proposition sentences (i.e., eight OS and eight SS sentences) that were selected randomly among the eight possible pages. The order of presentation of the simple and complex sentences was randomly determined for each participant. No time limit was imposed, allowing participants to revise their sequences and make changes as needed.

Data reduction

Each symbol received a code based on the order of appearance of the corresponding word in the spoken sentence: N1 = the first noun mentioned; N2 = the second noun mentioned; V = the action verb; W="wear" ("*porte*"); A = the attribute. Symbols not part of the target sentence were coded N- ("N minus"), V-, and A- for non-target nouns, verbs, and attributes, respectively. For instance, in response to the stimulus sentence "La fille pousse le clown qui porte un chapeau," ("The girl pushes the clown who wears a hat") the sequence of symbols *FILLE TIRE* ("pulls") *CLOWN PORTE CHAPEAU* was coded N1 V- N2 W A. All sequences were double coded and compared to identify discrepancies. Errors were resolved by application of the objective coding criteria. Individual patterns of response for each structure were analyzed. Because of the open-ended format of the response on this task, the number of possible responses is quite high, and it is impossible to establish a specific response pattern that could be associated to random responding. However, it was deemed very unlikely that a participant would, by chance only, produce the same type of sequence on half of the trials for a given structure. Therefore, participants were classified as exhibiting stability for a structure if they used the same sequence type on four or more of their eight responses. Participants with a stable pattern were then grouped based on the specific pattern they used. Again, all data was double checked, and although coding differences were rare (less than 5%), all discrepancies were corrected before conducting the statistical analyses.

Interpretation Task

The Interpretation task was the same task used in Sutton et al. (2010) and Trudeau et al. (2010). It followed the Construction task in order to avoid the possibility that previous viewing of the symbol sequences (Interpretation) would influence performance on Construction.

Stimuli

The stimuli were three- or four-symbol sequences containing the same symbols as used on the Construction task. There were 12 three-symbol stimuli: four target sequences and eight fillers. The target sequences followed French word order (e.g., *FILLE POUSSE CLOWN - GIRL PUSH CLOWN*: N1 V N2); the filler sequences presented other possible combinations of the same three symbols but did not follow canonical French word orders (*FILLE CLOWN POUSSE*: N1 N2 V and *POUSSE FILLE CLOWN*: V N1 N2). Eight target sequences and sixteen fillers were constructed by combining four pairs of noun symbols (*GIRL – CLOWN; BOY – CLOWN; CLOWN - GIRL; CLOWN – BOY*) with the two action symbols (*PUSH, PULL*). The four targets and eight fillers for each participant were a subset of these 24 sequences.

There were 24 four-symbol stimuli: 12 target sequences and 12 fillers. Target sequences were created by adding an attribute to the three-symbol target sequences, either after the first noun (e.g., *GIRL HAT PUSH CLOWN:* N1 A V N2) or the second noun (e.g., *GIRL PUSH CLOWN HAT*: N1 V N2 A). Fillers were created by adding an attribute to the three-symbol filler sequences (e.g., *GIRL HAT CLOWN PUSH* or *PUSH GIRL CLOWN HAT*). There were 32 target sequences and 32 fillers ($N = 64$), from which 12 of each were selected for each participant.

Participants were asked to choose a photograph for each sequence that was presented (targets and fillers). Only the data related to the target stimuli were included in the current analyses in order to mirror the targets in the construction task.

Materials

The photographs were digitized and arranged in arrays of four on a computer screen, similar to the arrays used in the Construction task. Each location on the screen was also numbered (1 through 4) to facilitate response selection when direct access to the screen was not possible. For the three-symbol sequences, the choices were: Correct action and N1 as the agent; Correct action and N2 as the agent; Incorrect action and N1as the agent; and Incorrect action and N2 as the agent. For the four-symbol sequences, the choices all depicted the correct action: N1 as the agent and wearing the attribute; N2 as the agent and wearing the attribute; N1as the agent and N2 wearing the attribute; and N2 as the agent and N1 wearing the attribute. Presentation of stimuli and response arrays, as well as automatic response recording, were accomplished through PowerLaboratory software (Chute, 1996) running on an iMac computer with default speech output settings turned on.

Familiarization and training

Participants were asked to select target symbols from an array to confirm that they remembered the meaning of each symbol from the Construction task. Then the experimental set-up for the Interpretation task was presented. The four photographs appeared on the computer screen and the participant selected one by pointing to the screen, pointing to a display containing the digits from 1 to 4, using eye gaze, or producing the numbers in speech. Eight practice trials were presented, in which a specific choice of photograph was not required. All participants were able to select one photograph from the array, thus successfully completing the familiarization phase. The materials used in this phase were similar to those in the actual experimental task, but the specific combinations of symbols were different. On each experimental trial, a green dot appeared at the center of the screen. When the experimenter activated the trial, the array of four photographs appeared on the screen and remained visible until the end of the trial. Five seconds after the photographs had appeared, the symbol sequence appeared on the screen above the photographs, one at a time at 1-s intervals, accompanied by speech output. The participant selected the photograph matching the symbol sequence, using his or her established response method. Twelve participants touched the photo of their choice on the screen, five pointed to digits on a board, one alternated between touching a screen and pointing to digits on a board; one used eye gaze to choose among four digits, one spoke the numbers, and two used partner-assisted scanning. Again, if the choice was not clear to the examiners, they confirmed the selection through scanning and yes/no procedures. All responses were recorded on the computer, either by the participant (direct access) or the examiner, after confirmation if necessary.

Data recording, coding, and scoring

For each of the target sequence types (N1 V N2, N1 A V N2, and N1 V N2 A) response patterns were classified as stable if the participant chose the photograph depicting the same relationship of the nouns to the verb (i.e., N1 = agent or N2 = agent); and for four-symbol sequences, the same relationship of the attribute to the nouns (i.e., N1 or N2 wearing the hat or scarf), on at least three of four trials for three-symbol sequences, and four of six trials for four-symbol sequences. This slightly higher criterion for the Interpretation task, compared to the Construction task, is justified by its closed-answer format. Participants whose response pattern was classified as stable were then sorted by the actual strategy they used (i.e., choice of N1 or N2 as the character performing the action and, when relevant, the choice of N1 or N2 as wearing the attribute).

Analyses

Descriptive data regarding each task and structure was tabulated for each participant. Individual response patterns (stability and strategy used) were examined on the two tasks. Relationships between variables of interest (e.g., stability and strategy choice, interpretation and construction patterns) were explored using chi-square tests. Two groups were formed based on the participant's use of a stable strategy on a given task, which were then compared on background variables (e.g., age, gender, language skills) using non-parametric statistical tests (e.g., Mann-Whitney, chi-square). Statistical significance level was set at 0.05. However, because multiple tests were performed on the data set, the significance of the results was also gauged against a stricter criterion of 0.005. Results meeting this second criterion were labeled as significant, while results meting the 0.05 cut-off but not the 0.005 one were labeled as marginally significant.

RESULTS

The stability of each participant's response pattern was examined for each structure and each task (see Table 2). On the Construction task, 15 participants (68%) showed stability on all structures, whereas 5 (23%) did not show stability on any of the three structures. The other two participants showed stability on one (simple) or two (simple and OS) structures. Looking at strategy choice for each structure, on the simple sentences, 15 of the 17 participants who responded in a stable manner (88%) constructed sequences that followed the spoken word order (i.e., N1 V N2: *GIRL PUSH CLOWN* for "The girl pushes the clown"). On the OS structure, 15 of the 16 stable participants (94%) constructed the same type of sequence, namely N1 V N2 (W^2) A (e.g., *GIRL PUSH CLOWN (WEAR) HAT* for "The girl pushes the clown who wears a hat"). On the SS structure, however, participants were split between two main strategies: 7 of 15 participants (43%) with a stable response pattern constructed the sequence N1 (W) A V N2 (e.g., *GIRL (WEAR) HAT PUSH CLOWN* for "The girl who pushes the clown wears a hat"). These participants distinguished between the two types of spoken sentences, and modified the graphic-symbol sequence relative to the spoken word order. In contrast, seven participants constructed a sequence that followed the order of the constituents in the spoken sentence (i.e., N1 V N2 (W) A) and constructed sequences that were identical to those used for OS sentences. In summary, the majority of participants used stable patterns of responses on each sentence type. In addition, on simple and OS structures, the preferred strategy was clearly to adhere to the spoken word order. On the SS structure, participants were split between adhering to the spoken model, and rearranging the sequence to eliminate ambiguity.

On the Interpretation task, 12 participants showed stability on all sequence types (N1 V N2, N1 A V N2, and N1 V N2 A), three did so on none of the structures and seven were stable on one or two of the three sequence types, with the majority of them ($n = 4$) showing stability only on the three-symbol sequences. Seventeen participants (77%) responded consistently on the three-symbol sequences, while 15 (68%) did so on N1 V N2 A, and 13 (59%) on N1 V N2. For three-symbol sequences, 15 of the 17 (88%) participants showing stable response patterns consistently chose the photo depicting the correct verb and N1 as agent. On N1 V N2 A sequences, the 15 stable participants all chose the photo depicting N1 as agent, and the attribute assigned to N2. On N1 A V N2, all stable participants ($n = 13$) chose N1 as the agent and also wearing the attribute.

Links Between Construction and Interpretation

The stability of each participant across tasks was examined to investigate the possible links between constructing and interpreting symbol sequences (see Table 3). Separate analyses were conducted for each structure type. For simple sentences (i.e., three-symbol sequences on the Interpretation task), the majority of participants showed a symmetrical pattern: stable on both ($n = 15$) or stable on neither task ($n = 3$). The pattern was asymmetrical for only four participants: stable on construction but not interpretation ($n = 2$), or stable on interpretation but not construction ($n = 2$). This distribution was not random, χ^2 (1,22) = 5.119, $p = 0.024$ and supports a marginal relationship between interpretation and construction. The majority (18/22) showed stability on the two tasks for this structure or did not respond consistently on either.

On the OS structure (i.e., NI V N2 A sequences on the Interpretation task), 14 participants were stable on both tasks whereas five did not show stability on either task; two with an asymmetrical pattern were stable on construction but not

TABLE 2 Number (and Percentage) of the 22 participants Showing Intra-individual Stability and Inter-Individual Stability on Construction and Interpretation for each Structure.

	Construction		Interpretation	
Structure	Intra-individual stability	Inter-individual stability	Intra-individual stability	Inter-individual stability
Simple – N1 V N2	17 (77.3)	15 (68.2)	17 (77.3)	15 (68.2)
OS – N1 V N2 A	16 (72.7)	15 (68.2)	15 (68.2)	15 (68.2)
SS – N1 A VN2	15 (68.2)	7* (31.8)	13 (59.1)	13 (59.1)
All	15 (68.2)	N/A	12 (54.5)	N/A

Note. Intra-individual stability = the number of participants showing a stable response pattern (50% and above on construction; above 50% on interpretation); Inter-individual stability = the highest number of participants agreeing on the same strategy; N/A = not applicable
*Two groups of seven participants each used a common strategy on this structure.

TABLE 3 Number (and Percent) of the 22 Participants Showing each Stability Profile Across tasks for each Structure.

	Stability			
Structure	Interpretation only	Construction only	Both	Neither
Simple – N1 V N2	2 (9.1)	2 (9.1)	15 (68.2)	3 (13.6)
OS – N1 V N2 A	1 (4.5)	2 (9.1)	14 (63.6)	5 (22.7)
SS – N1 A V N2	1 (4.5)	3 (13.6)	12 (54.5)	6 (27.3)
All	1 (4.5)	4 (18.2)	11 (50.0)	6 (27.3)

interpretation; the third participant showed the reverse pattern. The distribution was not random, χ^2 (1,22) = 10.1, $p = 0.001$. On the SS structure (i.e., N1 A V N2 sequences on the Interpretation task), 12 participants were stable on both tasks whereas six did not show stability on either task; three participants with an asymmetrical pattern were stable in construction but not interpretation, while one participant showed the reverse pattern. This distribution was not random, χ^2 (1,22) = 8.5, $p = 0.004$, confirming the same trend in the complex structures as for the simple structure.

Since seven participants constructed N1 V N2 A for two different structures (OS and SS relatives), it is possible that, when presented to them, such a sequence could be interpreted as both structures (cf. Sutton et al., 2004). In order to verify this, another analysis took into account the actual strategy chosen on N1 V N2 A sequences. Five of the seven participants who constructed N1 V N2 A in response to both OS and SS sentences interpreted the corresponding sequence as an OS utterance, and two used an unstable response pattern. This was similar to the distribution of profiles shown by the subgroup ($n = 8$), who constructed different sequences in response to SS and OS sentences, and seven interpreted N1 V N2 A sequences as conveying an OS structure, χ^2 (1,15) = 0.603, $p = 0.438$.

Link Between Language Skills and Performance on the Experimental Tasks

On each experimental task, we compared the language scores of participants who showed a stable pattern of responses on all structures to those who did not. The first measure used was the raw score on the ÉVIP, because in many studies receptive vocabulary scores are the sole measure of language achievement (see Table 1 for individual scores). There was no significant difference in ÉVIP scores between the participants showing or not showing stability on Construction (stable responders $\bar{x} = 91.5$, $SD = 73.5$; others $\bar{x} = 61.9$, $SD = 25.8$; $U = 27.5$, $p = 0.078$) or Interpretation (stable responders $\bar{x} = 88.1$, $SD = 67.8$; others $\bar{x}$ 74.8, $SD = 44.8$; $U = 46.5$, $p = 0.381$). The second measure of language proficiency used was the score obtained on the ÉCCW. Scores on this measure differed significantly between participants who showed stability and those who did not. Participants with stable response patterns obtained scores that were significantly higher on this measure for Construction (stable responders $\bar{x} = 101.8$, $SD = 94.5$; others $\bar{x} = 78.3$, $SD = 64.2$; $U = 8.5$, $p = 0.001$) and marginally higher for Interpretation (stable responders $\bar{x} = 101.9$, $SD = 95.0$; others $\bar{x} = 85.2$, $SD = 70.8$; $U = 28.5$, $p = 0.036$).

The same analyses were carried out including only participants who showed stability on the Construction task, but separating this time those who constructed the same sequences for both types of complex sentences (ÉVIP $\bar{x} = 85.9$, $SD = 62.2$; ÉCCW $\bar{x} = 101.9$, $SD = 92.0$), and those who made a distinction between the two structures (ÉVIP $\bar{x} = 91.0$, $SD = 57.5$; ÉCCW $\bar{x} = 98.9$, $SD = 85.0$). The differences were not significant (ÉVIP $U = 21.5$, $p = 0.701$; ÉCCW $U = 23.0$, $p = 0.613$).

Other Differences Between Subgroups of Participants

The final step of the analyses investigated whether other characteristics of the participants were linked to their response patterns (stable or not stable) on the two tasks, or may have confounded the findings. The subgroups did not differ in age for Construction (stable responders $\bar{x} = 30.8$, $SD = 23.1$; others $\bar{x} = 23.6$, $SD = 11.7$, $U = 38$, $p = 0.33$) or Interpretation (stable responders $\bar{x} = 28.5$, $SD = 18.5$; others $\bar{x} = 28.7$, $SD = 20.1$, $U = 58.5$, $p = 0.923$).

The second variable considered was the cognitive abilities of the participants. Because of the wide range of abilities displayed, two different measures were used (CMMS or TONI, depending on level). Therefore, rather than using scores for this comparison, participants were grouped into three cognitive levels as established through formal testing, and broad age-equivalent (AE) levels. Group A included participants whose skills were the lowest ($n = 10$, AE at or below 6 years); Group B represented the middle range within the sample ($n = 6$, AE above 6 and below 12); and Group C were the participants who performed best on the formal IQ test ($n = 6$, AE at or above 12). The specific cut-off scores were chosen based on previous work involving participants without disabilities (Sutton et al., 2010; Trudeau et al., 2007; in press) that documented differences in the performance of preschool children (i.e., current Group A), school-aged children (i.e., current Group B), and teens and adults (i.e., current Group C). The distribution of the response patterns (stable on all structures vs. not) on each experimental task across these three subgroups was then analyzed. For the Construction task, the distribution was marginally significant: likelihood ratio χ^2 (2,22) = 7.1, $p = 0.029$. In Group A, only four of the 10 participants showed stability, whereas this was the case for five of the six participants in Group B and all six participants from Group C. A similar distribution pattern was observed on the Interpretation task: three of the 10 participants in Group A showed stability, as did four of the six participants in Group B, and five of the six in Group C; however, this relationship did not achieve statistical significance: likelihood ratio χ^2 $(2,22) = 4.8$, $p = 0.091$.

Because of the great heterogeneity in the sample, several variables linked to the participants' AAC systems, experience, and personal characteristics were also explored (see Table 1 for individual data on these variables). Specifically, gender, bilingualism, the severity of the motor impairment, the access method used by the participant during testing, and the presence of voice output on the participant's device, were explored using chi-square tests. None of these variables showed a relationship with response patterns (all p-values between 0.08 and 0.95). Similarly, Mann-Whitney tests showed that the number of symbols on the participant's system, their total years of experience with AAC, and the length of time they had been using their current system, did not differ between groups of participants with or without stable response patterns (all p-values between 0.28 and 0.92).

DISCUSSION

The goals of this study were to describe how individuals who use graphic symbols for daily communication construct graphic-symbol sequences and interpret such sequences, and to explore how individual characteristics of the participants were related to their response patterns.

The majority of participants used a stable response pattern on all of the structures in the Construction task (15 to 17/22, depending on the structure). Although a stable construction pattern is an important step in scaffolding a stable interpretation of graphic-symbol sequences, it does not in itself guarantee the successful transmission of the intended messages. The strategy chosen could influence the communication partner's understanding of the sequence of graphic symbols. Since the communication partners of most AAC users have speech as their communication modality, a promising strategy would be to construct sequences that mirror as closely as possible the syntax of the spoken language. Participants tended to maintain the spoken word order in their responses. In fact, for simple sentences, all participants constructed a subject-verb-object sequence. Similarly, all participants but one reproduced the spoken word order in their OS graphic-symbol sequences. For SS structures, participants were split between two types of graphic-symbol sequences: one that followed spoken word order, and the other that did not. In this case, adhering to spoken word order resulted in constructing identical sequences (N1 V N2 A) to convey two different meanings: OS and SS relatives. Taken together, these results show a strong tendency for experienced AAC users to rely on the syntax of their surrounding language to construct sequences of graphic symbols, and, for some of them, the ability to move away from the spoken model when required by the context.

A similar number of participants responded consistently on each structure on the Interpretation and Construction tasks (13 to 17/22). In Interpretation, when participants responded in a stable manner on a structure, they overwhelmingly chose the interpretation predicted based on the spoken word order of their native language. This reinforces the conclusions that spoken language is a strong mediator in graphic-symbol communication.

Links Between Construction and Interpretation Tasks

The literature suggests two possible scenarios regarding the relationship of performance across tasks. Findings of studies involving participants without disabilities would predict that the ability to interpret graphic-symbol sequences should precede the ability to construct them. Further, the Construction task used an open response format (i.e., participants could construct any sequence they wanted to), but the Interpretation task included only four response options. However, the asymmetry in AAC users' experience may boost their construction abilities relative to interpretation (or at least reduce the gap that was reported in the studies of participants without prior AAC experience). Five participants showed an asymmetry in construction and interpretation across structures. In four of them, overall stability was observed on the Construction task, but not the Interpretation task, lending support to the second scenario. When looking at specific structures, however, the distribution of asymmetrical profiles was more balanced. Nonetheless, no clear signs of interpretation preceding construction were observed in this study.

The actual choice of strategy provides insight into what participants were doing. On simple sentences, because all participants chose strategies coherent with spoken language order, the relationship between specific interpretation and construction of sequences is straightforward. However, on complex utterances, seven of the participants constructed the same graphic-symbol sequence to convey SS and OS sentences (i.e., N1 V N2 A). It would be reasonable to hypothesize that both interpretations (SS and OS) would be observed among these participants when presented with the N1 V N2 A sequence for interpretation, but this was rarely the case. Five of these seven participants clearly interpreted N1 V N2A sequences as an OS structure but also clearly interpreted N1 A V N2 as an SS structure, even though they had not constructed such sequences in response to SS sentences. These observations suggest that the reason that participants did not distinguish between the two complex structures on the Construction task was not an inability to comprehend the alternative sequence. They may have attempted to reproduce the spoken model as closely as possible, or they may not have noticed that they were constructing the same sequence for two different stimuli. This response pattern (i.e., not constructing a sequence that they could still interpret) is in line with the performance of some novice (e.g., Trudeau at al., 2007; in press) and experienced participants in previous studies (Sutton et al., 2004).

Factors Influencing Performance on Graphic-Symbol Tasks

Language abilities were expected to play a role in the ability to transpose and interpret graphic-symbol sequences, based on the developmental trends observed in earlier studies (Trudeau et al., 2007; in press). In the current study, receptive vocabulary skills were not linked to the use of a stable response pattern, possibly because the lexical demands of the tasks were fairly low (i.e., only eight symbols to learn) and participants had learned the symbols prior to the tasks. Furthermore, all participants were familiar with handling larger displays (minimum size over 30 symbols). In contrast, participants with better receptive syntactic skills showed more stable response patterns when constructing and interpreting sequences of symbols, lending support to the idea that oral receptive skills may facilitate (or at least correlate with) interpretation and use of graphic-symbol communication. This relationship had been observed at the single symbol level (Sevcik, 2006; Stephenson, 2009), and the current results extend its application to symbol sequences.

Cognitive level showed an association with the stability of response patterns. This could reflect either a link between overall cognition and language level or the distinct contribution of some specific cognitive skills. Although the current study did not attempt to distinguish among different cognitive components, some skills that should be considered more specifically in future studies would include short-term memory, visual perception, and metalinguistic skills. The fact that chronological age did not show an effect is undoubtedly a reflection of the heterogeneity of developmental paths followed by individuals who use AAC. Because of the variety of physical, linguistic or cognitive limitations, chronological age may be a poor indicator of developmental level in this population. The absence of significant differences based on chronological age actually strengthens the findings regarding language and cognition as independent contributors to performance on the tasks. Furthermore, the finding that participants with and without consistent response patterns did not differ on any of the AAC-system use variables (type, size, duration, access mode, etc.) suggests that the details of the actual AAC experience is not what matters most in a person's ability to adopt strategies when using graphic symbols. Similarly, the severity of the motor impairment was not related to participants' performance on the current tasks.

Clinical Implications

The participants who did not have stable response patterns used a very wide variety of sequences (sometimes as many different sequences as there were items), and did not come close to demonstrating stability in their constructions. It is quite clear from these data that these participants, although they could construct symbol combinations, did not understand how to map a spoken sentence onto graphic symbols. If consistent patterns in construction increase the likelihood that a message will be interpreted accurately, clinicians may want to explore how to develop strategy use in their clients using AAC. In most cases, stable performance was linked to a strategy that was consistent with the spoken language of the participants' community. However, the specific strategy applied may not need to match the spoken syntax perfectly, as long as the communication partners know what the particular "code" is.

In some participants, the construction of different sentences using the same sequence of graphic symbols coexisted with a clear ability to understand alternative sequences that would have been clearer to the communication partners in real-life communication contexts. In other cases, the interpretation of graphic-symbol sequences was not as stable as one may have predicted, based on the construction of matching sequences by these participants. In such cases, drawing a client's attention to how they might interpret their own constructions may be a logical step towards their being able to actually predict how partners would interpret such constructions.

This study was conducted in a controlled environment, following procedures that differ from natural conversation. This made it possible to collect a large set of data in a context where the target was controlled and the lexical demands were kept low. In this constrained setting, comprehension of spoken syntax and cognitive level were the best predictors of performance. The fact that ÉVIP scores were not linked to performance, but ÉCCW scores were underlines the importance of not using lexical measures as the sole indicator of language skills in individuals who use AAC. The current results suggest that assessing receptive syntax is key in developing an accurate portrait of linguistic skills in this population, and may assist the clinician in selecting intervention targets such as complexity of symbol combinations. The current results also show that receptive vocabulary and cognitive level may contribute independently to the syntactic performance of individuals who use AAC, and thus warrant specific evaluation.

It is somewhat reassuring to know that characteristics of the AAC system used by the participants, as well as the severity of their motor impairments, did not have a significant impact on their performance on the tasks. This confirms that when it comes to AAC, intervention should not be dictated by the availability of technology, the apparent challenges imposed by severe motor impairments, or other such factors. While intervention and tools should always aim at optimizing the client's potential, the current results show that even individuals using simple communication systems without direct access were able to consistently construct sequences of symbols corresponding to both simple and complex sentence structures.

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Notes

1. In order to avoid confusion, throughout this article, the terms *production* and *comprehension* will be used to refer to the expressive and receptive domains of the oral modality, whereas *construction* and *interpretation* will be used as the corresponding terms for the graphic-symbol modality.
2. In all analyses, the use of the symbol *WEAR* was considered optional, since it was the only symbol that did not need to be contrasted with another in order to make the message clear. In previous work, we found that considering *WEAR* as optional vs. mandatory did not impact the results of the analyses.

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