

# The Role of Word Order in the Interpretation of Canonical and Non-Canonical Graphic Symbol Utterances: A Developmental Study<sup>‡</sup>

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Graphic symbols are often used to represent words in Augmentative and Alternative Communication systems. Previous findings suggest that different processes operate when using graphic symbols and when using speech. This study assessed the ability of native speakers of French with no communication disorders from four age groups to interpret graphic-symbol sequences of varying length and canonicity. Results reveal that, as they get older, participants show an increase in their capacity to interpret graphic-symbol sequences. Constituent order played an important role in the interpretation of the sequences. However, the specific word-order strategies used varied depending on the age group and the type of sequence presented.

*Keywords:* Graphic symbols; Utterances; Augmentative and alternative communication; Word-order strategies

## INTRODUCTION

Understanding how communication partners interpret graphic symbol sequences is an important issue in AAC. From a clinical standpoint, partners are often relied upon to extract meaning from messages that may not follow traditional syntax, or may be incomplete, because the use of graphic symbols to communicate sometimes leads to the production of utterances that do not follow the canonical word order of the spoken language of the environment (see Smith & Grove, 2003; Soto 1999; Sutton, Soto, & Blockberger, 2002, for reviews). Sequences that differ from the expected word order may be a consequence of, for example, limits on the number of vocabulary items that are included on a display or device; reduced availability of grammatical markers (compared to content words such as verbs and nouns); and strategies used by the person who uses AAC to compensate for the absence of a particular symbol on the display or to generate the message more quickly. Production of graphic symbol utterances that do not follow the canon-

ical word order of spoken sentences are not rare, even by participants who produce canonical structures orally. For instance, Smith (1996) reported that preschool aged children ( $n=5$ ) who produced complete subject-verb-object (SVO) sentences orally in response to a picture stimulus did not necessarily do so when responding in the graphic symbol modality. Almost half (48%) of their descriptions included only one symbol, and a third (35%) included two symbols only, even though the target included three symbols. Similarly, Sutton and Morford (1998) reported that children aged 6 to 13 years ( $n=32$ ) adhered to English SVO word order when using spoken sentences to describe non-reversible transitive actions (97% or more), but not when using graphic symbols, especially younger children (34% to 89%). Here again, a large proportion of the children's productions included fewer symbols than expected, based on the oral sentence produced. A recent study spanning a wider age range confirmed very low levels of adherence to spoken word order by 3- and 4-year-old children when producing sequences of graphic symbols on

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<sup>‡</sup>Kathryn Drager acted as Editor for the review of this paper.

a sequence construction task, even for simple SVO sentences (Sutton, Trudeau, Morford, Rios, & Poirier, 2010); but improvement in performance between the school-age period, the early teenager years, and adulthood (Trudeau, Sutton, Dagenais, de Broek, & Morford, 2007). However, even adults tend to omit more words in graphic symbol utterances than when speaking (Nakamura, Newell, Alm, & Waller, 1998).

Studies exploring interpretation of sequences of graphic symbols also suggest that listeners rely on word order. English-speaking adults, when given a sequence that could be interpreted either as a subject or an object relative clause, such as *GIRL PUSH CLOWN WEAR HAT* (i.e., corresponding to either “The girl who pushes the clown wears a hat” or “The girl pushes the clown who wears a hat”), overwhelmingly interpreted it as an object relative, attributing the hat to the clown, rather than the girl. This observation suggests that, at least for adults, physical and temporal proximity of the symbols in the sequence (i.e., word order) may be an important cue when interpreting graphic symbol sequences that could be ambiguous (Sutton, Gallagher, Morford, & Shahnaz, 2002).

In addition to its clinical significance, the study of graphic-symbol sequence interpretation is important from a theoretical point of view because it may shed light on broader language-based strategies in sentence interpretation. Comparing the interpretation strategies used in the context of graphic-symbol use to those studied in the context of spoken language processing should also help clarify the relationship that exists between these two modalities.

When interpreting a spoken utterance, listeners may use several sources of information (i.e., cues) that vary according to the language and the utterance characteristics. Cues may at times compete against each other, pointing to different interpretations of a given structure (MacWhinney & Bates, 1989). The reliability of a particular cue may vary among languages and among users of the same languages at different levels of learning/proficiency. The Competition Model, proposed by MacWhinney and Bates, has been used widely to analyze and evaluate strategies used by individuals and communities in interpreting sentences in different spoken languages (see Gibson, 1992, for a critique of this theoretical framework). This model is particularly well suited to psycholinguistic experimental paradigms, as it provides a framework that can be used to study sentence processing in contexts that attempt to keep to a minimum some of the pragmatic and situational variables that are present in real-life interactions.

The Competition Model posits that when trying to assign function (meaning) to a sentence, the listener must assess different cues with regards to their validity. A cue is deemed valid overall if it is frequently available in a given language, and if it is reliable, in that it tends to lead to a correct interpretation when used. When only one cue is present, two characteristics – availability and reliability – should determine whether the listener chooses to rely on the cue to interpret the sentence. However, it is very common in spoken language for several cues to be available concurrently. If they all point to the same interpretation, the listener’s decision will be confirmed. However, if conflicting cues are present, the decision process will be based on the weighted likelihood that disregarding one cue or the other will yield a correct interpretation. The ability to resolve a conflict will be influenced, among other things, by the individual’s propensity to follow a specific cue (i.e., cue strength). In this framework, language development can be viewed as the process that allows cue strength to converge with cue validity. For a young child whose processing capacity is limited, some cues may be too costly to attend to, either because they are difficult to perceive (perceptually or conceptually), or they require that too much information be kept in memory before proper interpretation. Therefore, MacWhinney and Bates proposed that children first use cues based on their availability, then adjust their use based on reliability, and only later are able to fine-tune their interpretation of conflicting cues. This evolution may involve abandoning a cue that was very strong at some point in development, in order to adopt others that have become more clear or reliable, easier to perceive, or more manageable to the listener as their processing abilities evolve. This may result in U-shaped learning curves, where early on children do not notice a cue, then become aware that it is there and use it, and then realize that other cues are better and lower the reliance on that particular cue. In that perspective, studies that investigate strategy use across different age groups using a common methodology could document this type of strategy change over the lifespan.

Among the cues that assist in spoken sentence interpretation, the use of word order has been studied extensively across development. Infants are highly sensitive to linear sequencing of auditory stimuli, and by 12 months can distinguish between sequences that are allowed or not by an artificial grammar after less than 2 min of exposure to utterances generated by the grammar (Gómez & Gerken, 1999). By 15 months they can extend this ability to non-adjacent sequences, that is, a predictable sequence that is interrupted by a

novel element – aXb, where the *a* and *b* elements are repeated across the grammar, but the intervening *X* element is a novel element in each trial (Gómez & Maye, 2005). Thus, children are able to track word order in speech long before they apply it to interpreting the meaning of actual utterances. English- and German-speaking children as young as 21 months (Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008; Gertner, Fisher, & Eisengart, 2006), or with an average utterance length of over 3 morphemes (de Villiers & de Villiers, 1973), consistently use a word order strategy in comprehension under some task conditions, interpreting the first noun in orally presented NVN reversible sentences (i.e., where either noun could logically be the agent of the action) as the agent. At this age, children make errors when interpreting passive sentences. Reliance on word order has also been demonstrated for bilingual children (Reyes & Hernandez, 2006) and French-speaking children aged 5 years to 8 years (Vion & Amy, 1984). When applied to graphic symbols, these findings suggest that children at a young age should be sensitive to constituent order in graphic-symbol sequences, at least in NVN sequences.

However, word order, as a strategy, also competes with other cues that may sometimes override it, such as lexical/semantic cues (e.g., in Italian, Bates et al., 1984; in Chinese, Miao, Chen, & Yin 1984) or grammatical cues (e.g., in French, Kail & Charvillat 1988; in Arabic, Taman, 1993). Moreover, the reliance on specific cues and the relative weight granted to each vary considerably from one language to another. For instance, it has been repeatedly shown that Italian children and adults rely strongly on semantic cues (e.g., interpreting the cow as the agent in “The pencil kicks the cow”), whereas English speakers adhere to canonical English word order in their interpretation, assigning the first noun (e.g., the pencil) to the agent role (Bates, MacNew, MacWhinney, Devescovi, & Smith, 1982; Bates et al., 1984). In a subsequent study, Kail (1989) found that French speakers gave word order more weight than the Italian speakers, but less than the English speakers. These findings suggest that English- and French-speaking individuals would likely rely on word order cues in the interpretation of graphic-symbol sequences.

Use of word order as a strategy for spoken utterance comprehension is also influenced by whether or not the utterance is canonical in form (Slobin & Bever 1982). In their cross-linguistic study of English and Italian, Bates et al. (1984) found that interpretation strategies for non-canonical sequences, that is, sequences that did not conform to the usual NVN=SVO word

order (NNV and VNN), varied based on the native language and the age of the participants. The sequences where the two nouns were animate are particularly interesting with respect to word order strategies, because animacy cannot be used to help decide which noun is the agent. On those types of utterances, Bates et al. observed that participants rely on the same cues for interpreting both canonical and non-canonical sequences. Specifically, the Italian participants showed a greater reliance on semantic cues, while American participants relied on word order. In a more recent study, Akhtar (1999) demonstrated that 4-year-old children, when taught novel verbs in structures that violate the expected word order (e.g., SOV and VSO rather than SVO), automatically resorted to SVO structures in their own productions of these novel verbs, showing a very strong adherence to the canonical word order in their learning. Taken together, these findings would suggest that (a) if word order is important in a spoken language, listeners should rely on word order cues to interpret non-canonical symbol sequences, and (b) specific word order strategies should appear, rather than random responding.

The specific strategies used to interpret spoken structures have been shown to vary with age. For instance, Lempert and Kinsbourne (1980) reported that, when interpreting reversible sentences, younger English-speaking children (3 to 4 years of age) tend to choose one of two strategies (first noun = agent or noun immediately before verb = agent) regardless of the structure presented, resulting in systematic errors on some types of sentences. In contrast, older English-speaking children (5 to 6 years of age) responded very consistently on some structures but inconsistently on others. Lempert and Kinsbourne suggested that the pattern exhibited by older children may reflect an increase in flexibility when applying interpretation strategies. Studies conducted in French have also looked at the interpretation of structures with varied word order, some canonical, and some non-canonical. Kail (1989), in particular, investigated the processing of NVN, VNN, and NNV structures in children aged 2;6 (years;months), 3;6, 4;6, and 5;6 and in adults. In the subset of items where both nouns were animate, she observed a trend during early childhood (2;6 to 5;6) to increasingly choose the first noun (N1) as agent in canonical sequences (from 65 to 100%), although adults showed a much weaker preference for N1 = agent (68%). For non-canonical VNN sequences, there was a tendency to choose N1 as agent starting at 3;6 years of age; and for NNV sequences, there was a trend toward N2 = agent in children, as

opposed to N1=agent in adults. The same authors also studied the effect of the presence of a clitic pronoun (a weak form of the personal pronouns, potentially marked for gender, person, and number) on sentence interpretation by slightly older participants. They found that, in the absence of a clitic pronoun, NNV structures lead to significantly slower processing than NVN structures, but the introduction of a clitic pronoun eliminated the difference in reaction time in all participant groups (6;6, 8;6, 10;6 and adult). In this case, the mere presence of the clitic provides a canonical structure for the listener, improving speed of processing. These findings suggest that developmental trends should emerge in the interpretation of canonical and non-canonical sequences of graphic symbols, with possibly an increased variability (i.e., flexibility) with improved competence.

### The Present Study

Exploration of how canonical and non-canonical graphic symbol sequences are interpreted by listeners across development could lead to a better understanding of how communication partners approach the task of interpreting actual utterances produced by individuals who use graphic symbols for communication. In addition, graphic symbol sequences present a unique context in which to study interpretation strategies for canonical and non-canonical word orders. The present study was therefore designed to extend the exploration of word order strategies in the interpretation of graphic symbol sequences, by systematically evaluating the effects of utterance length (three or four symbols) and the canonical or non-canonical nature of the sequences, on interpretation of graphic symbol sequences by participants at different levels of language development (preschool-age to adult).

The literature on interpretation of spoken word order suggests that listeners may apply one of several strategies when presented with a non-canonical order (e.g., Bates et al., 1984; Charvillat & Kail, 1991). If this is the case for graphic

symbol sequences, listeners may use the same strategy across canonical and non-canonical sequences or different strategies, depending on the particular sequence type (see Table 1 for a summary). The simplest strategy would be to interpret the agent and patient roles based on first mention (FM) because this strategy can be applied as soon as a noun has been identified, regardless of the placement of the nouns relative to the verb. From a processing perspective, this strategy imposes the lowest cognitive cost because it does not require an analysis of the sequence as a whole. An FM strategy would lead to interpreting the first noun (N1) mentioned as having the same role (e.g., N1 = agent), whether it appeared before or after the verb of the sequence. A second possible strategy would be to attempt to apply SVO word order to the greatest extent possible (cf. Bates et al., 1984). According to this SVO Preservation (SVO-P) strategy, participants would identify a sequence that conforms to SVO order (e.g., NNV becomes N-SV) and assign the remaining elements to the unassigned roles (e.g., N-SV becomes OSV). This strategy is somewhat more demanding cognitively because it requires an alignment of two different sequences. A third and final strategy would involve relying on some less frequent oral structures that parallel the non-canonical sequence of major constituents (LFS strategy). In this case, the listener would assimilate the non-canonical sequence to a canonical one, by filling in clitics (pronouns) when interpreting the symbol sequence so that it corresponds to a spoken language structure in which non-canonical word order is permitted, for example, *CLOWN FILLE POUSSE* being considered as “Le clown, la fille le pousse” (The clown, the girl pushes him); or “Le clown, la fille, il la pousse” (The clown, the girl, he pushes her), consistent with the analysis of Charvillat and Kail (1991) for spoken sequences. Similarly, *POUSSE FILLE CLOWN* could be processed as the imperative, “Pousse la fille, clown!” (Push the girl, Clown!), or as a sentence with a clitic, “Il pousse la fille, le clown” (He pushes the girl, the clown). As with the SVO-P strategy, this strategy

TABLE 1 Possible Strategies for Interpreting Non-canonical Spoken Utterances.

Strategy	Description	Attribution of agent role		
		Canonical	N1 N2 V	V N1 N2
First mention (FM)	N1 = agent	N1	N1	N1
SVO preservation (SVO-P)	Try to apply SVO; Interpret pieces that look like SVO with SVO roles: N V = SV; V N = VO; assign remaining N to other role	N1	N2	N2
Less frequent structures (LFS)	Add pronouns to assimilate to cleft structure	N1	N1 or N2	N1 or N2

carries a greater cognitive burden than the FM strategy because it requires consideration of the sequence as a whole in order to determine how a modification would lead to a match to a canonical order. While less frequent structures (LFS) exist in French for all possible combinations of S, V and O, if clitics are present, SOV and OSV are the most common non-canonical structures, while VSO and VOS are relatively rare (Kail, 2004). Thus, the LFS strategy leads to the additional prediction that response patterns should be more consistent for verb-final than for verb-initial sequences.

In sum, the study addresses the following research questions:

- (1) To what extent do participants rely on word order cues when interpreting graphic-symbol sequences? The literature on spoken utterance interpretation would predict that speakers of French should be sensitive to word order early on, whether or not the presented utterance follows a canonical sequence.
- (2) What changes in the use of word order cues in the interpretation of graphic-symbol sequences of varying length can be identified between early childhood and adulthood? The competition model would predict that the use of word order as a cue to interpret graphic symbol sequences would evolve with age. Based on the empirical results reviewed, one might expect that although word order may be a relevant cue from early on, the specific way in which it is used to make sense of the sequences (i.e., strategy) is likely to change over time, with younger children showing less obvious reliance on word order, reflected in inconsistent responding, followed by a period where stricter rules of word order are applied, and finally, a period where interpretation becomes more flexible, with increased language competence. It is not clear whether these changes in strategy would occur at similar developmental levels as the ones observed in the processing of spoken sentences.
- (3) When constituent order conflicts with the canonical order of the native language (i.e., non-canonical orders), what strategies do participants rely on to interpret graphic symbol sequences? From what is known about spoken language processing, one may expect the non-canonical sequences would lead to increased variability in their interpretation, particularly for sequences that are less common (i.e., VNN for French speakers).

## METHODOLOGY

### Participants

The study received institutional ethics approval prior to the beginning of the recruitment efforts. Participants were recruited through ads posted in public places, daycare centers, day camps, schools, and universities across the greater Montreal area; or by word of mouth. A compensation of 10\$ per visit was offered to each participant, in order to cover parking or other transportation costs.

The participants were four groups of native speakers of French with no disabilities or language delays: preschool children ( $n = 30$  mean age = 4;0,  $SD = 8.2$  mo.), school-aged children ( $n = 29$ , mean age = 7;8,  $SD = 6.7$  mo.), teenagers ( $n = 30$ , mean age = 13;0  $SD = 6.6$  mo.), and adults over 18 years of age ( $n = 30$ , mean age = 27;4,  $SD = 11$  mo.). Integrity of receptive language skills was documented through the *Épreuve de compréhension de Carrow-Woolfolk* (ÉCCW) (Groupe coopératif en orthophonie- Région Laval, Laurentides, Lanaudière, 1995) for children and the *Échelle de vocabulaire en images Peabody* (ÉVIP) (Dunn, Thériault-Whalen, & Dunn, 1993) for all groups. All participants' scores were within normal limits on these language tests.

### Materials

The materials were graphic symbol sequences and photographs, presented on a MacIntosh computer via experiment management software.

### Stimuli

The stimuli were Picture Communication Symbol sequences containing 3 or 4 symbols (PCS, Johnson, 1994). Seven symbols (*PUSH*, *PULL*, *GIRL*, *BOY*, *CLOWN*, *SCARF*, *HAT*) were used in the tasks. Some sequences respected spoken French word order and are referred to as *canonical* while others violated the typical spoken French word order, and are referred to as *non-canonical*.

There were three types of three-symbol sequences. The first type, N1VN2 (e.g., *GIRL PUSH CLOWN*) was canonical (C-3). The second and third types were non-canonical and included sequences where the verb came after the two nouns (i.e., verb-final sequences (VF-3), e.g., *GIRL CLOWN PUSH*), or before the two nouns (i.e., verb-initial sequences, (VI-3) e.g., *PUSH GIRL CLOWN*). There were eight exemplars of each type, for a total of 24 three-symbol sequences. Twelve of these sequences were used with preschool children, 18 with school-age children, and all of them with the other groups. A smaller number of trials were used with younger

children to avoid fatigue and keep the protocol reasonably short.

There were three types of four-symbol sequences, each corresponding to one of the three-symbol sequences with the addition of an attribute to one of the nouns. The first type was canonical (C-4), and included two different sequences that were created by adding an attribute into the three-symbol canonical sequences, either after the first noun (e.g., *GIRL HAT PUSH CLOWN*), or the second noun (e.g., *GIRL PUSH CLOWN HAT*). Non-canonical types included VF-4, where the verb was placed after both nouns and the attribute (e.g., *GIRL HAT CLOWN PUSH*); and VI-4, where the verb was placed before both nouns and the attribute (e.g., *PUSH GIRL CLOWN HAT*). There were 32 canonical sequences, and 16 of each of the non-canonical sequences, for a total of 64 four-symbol sequences. Of these sequences, eight were used with preschool children, 24 with school-age children, and all of them with the other groups. Thus, the four-symbol sequences represented the same agent-action-patient options as did the three-symbol sequences, but were longer because of the addition of the attribute. We hypothesized that the attribute symbol would be interpreted in a consistent way as applying to the preceding noun (following French syntax). We also hypothesized that the two canonical sequences would be treated in the same way regarding attribution of agent role to N1.

### **Photographs**

The photographs depicted actions enacted by Playmobil figurines, as described in the stimuli. Photographs, representing a simple proposition, corresponded to the three-symbol sequences (e.g., a girl pushing a clown), and photos representing a complex proposition, corresponded to the four-symbol sequences (e.g., a girl pushing a clown wearing a hat). There were eight simple proposition photos, and 32 complex proposition photos, obtained by adding one of two attributes (hat or scarf) to one of the characters in the simple proposition photographs. The photographs were arranged in arrays of four, presenting minimal contrast between them, as shown in Figure 1 (e.g., a girl with a hat pushing a clown, a girl pushing a clown with a hat, a clown pushing a girl with a hat, and a clown with a hat pushing a girl). The specific position each photo occupied on the  $2 \times 2$  array was counterbalanced across trials.

### **Computer and software**

A computer with a dynamic-display touch-screen and voice output was used to display the

photographs and symbols in PowerLab (Chute, 1996) experimental software. Speech synthesis (default setting on the computer) was used to name each symbol as it appeared on the screen. Speech synthesis was included in order to give increased feedback to the participants, and to make sure that response patterns could not be explained by symbol confusion. Use of voice output also mirrored the conditions of the production tasks (see Trudeau et al., 2007) that were part of a broader research protocol, and is an increasingly standard practice in AAC systems used for communication.

### **Experimental design**

The experiment followed a  $4$  (age group)  $\times$   $2$  (sequence length)  $\times$   $3$  (sequence type) mixed design. All participants completed two experimental tasks (i.e., one task for each stimulus length). The order of the tasks was randomly determined for each participant. The order of presentation of stimulus sentences in each task was also randomized, so that items did not occur in the same order for each participant.

### **Procedures**

#### **Overall procedure**

All testing was carried out in a quiet location. Participants were met on two occasions. During the first session, participants completed the evaluation tasks, familiarization task, and a production task (Trudeau et al., 2007). During the second session, participants completed a familiarization refresher, training, and experimental tasks. All experimental sessions were carried out by research assistants (students in speech-language pathology or linguistics) who were trained by the third author to ensure uniformity of the procedures. Responses were automatically recorded by the PowerLab software.

#### **Familiarization and training**

Familiarization with the materials was provided during the first session, to ensure that all of the participants could recognize the symbols used in the protocol. All participants had also completed a production task, and were already familiar with the materials used. The familiarization refresher included identifying individual graphic symbols (i.e., *What's this?*), and choosing a target symbol among an array (i.e., *Show me \_\_\_*). The form of the verb that was taught and used in the trials was an inflected form (i.e., "pousse" and "tire")

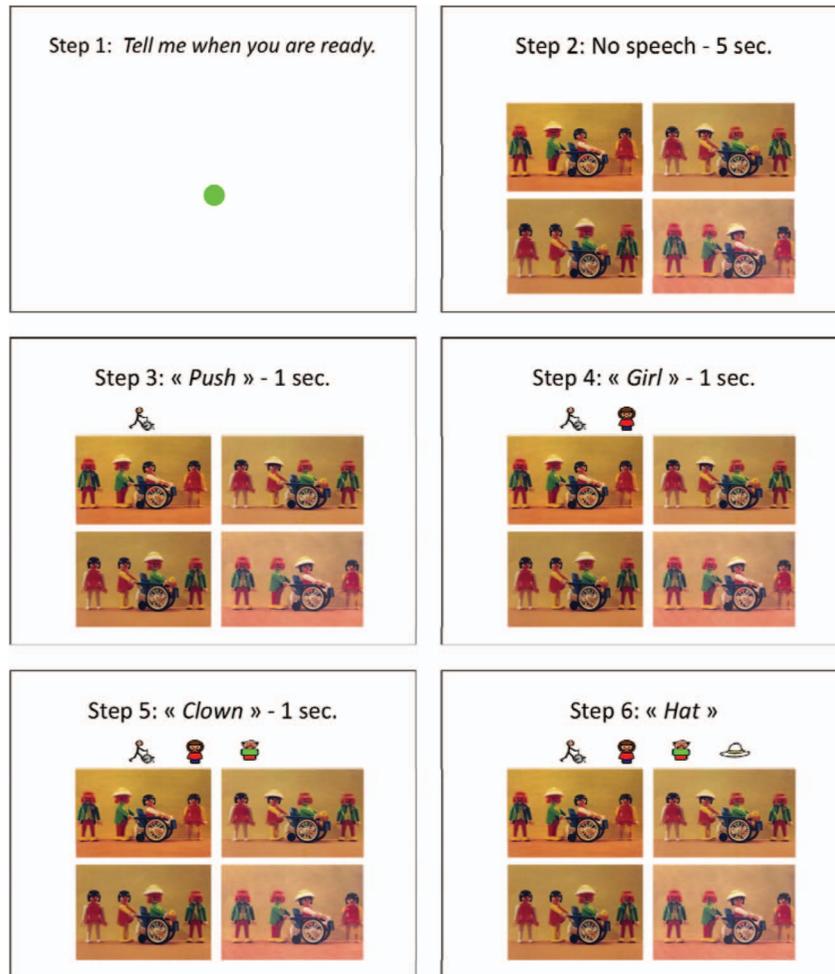


Figure 1. Example of a trial for the sequence *PUSH GIRL CLOWN HAT* (*POUSSE FILLE CLOWN CHAPEAU*).

corresponding to the most basic conjugated form in French (present tense, all persons singular and third person plural) comparable to the call form of the verb in English (e.g., push, pull). Training for the current study involved selecting photographs within a set of four according to a graphic symbol sequence provided. Participants received the following instructions:

You will see four photographs on the screen that you can look at for 5 seconds. After that time, symbols will appear, in a sequence, above the photos. The name of each symbol will also be spoken. Once all the symbols are displayed on the screen, your task is to choose, by touching it, the photo that you think best represents the sequence of symbols. When you are done, a green dot will appear on the screen.

The training materials used were similar to the ones in the experimental tasks although the actual 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).

#### **Task administration**

Participants were instructed that the experimental trial would proceed exactly like the familiarization trials they had just completed. On each trial, a green dot appeared in the center of the computer screen. When the participant indicated he or she was ready, the trial was activated and involved three steps: (a) the array of four photographs appeared (5 s); (b) the symbols were added one at a time above the array, at an interval of 1 s, each accompanied by a spoken label, and remained on the screen until the end of the trial; and (c) the participant selected the photograph in the array matching the symbol sequence by touching the screen. If needed, particularly for the younger children, a reminder was given at this point (e.g., *Which picture matches the symbols?*). Figure 1 offers a visual representation of a typical trial. A research

assistant manually tracked responses on a separate response sheet in addition to the automatic recording of responses by the computer. Following each testing session, the two records were checked for inconsistencies. This verification revealed 100% agreement between the automatic and manual data recording methods for the choice of picture.

### **Data reduction**

Each response was coded according to whether the photo selected depicted the first or second noun as the agent, and (for four-symbol sequences) whether the attribute had been assigned to the first or second noun. Inter-coder agreement was assessed for all responses. Agreement rates were well above 90% for all groups and all sequences. All disagreements were the result of coding mistakes, which were systematically corrected through this verification process.

### **Analyses**

There were two levels of analysis. First, data patterns were investigated at a group level. For each sequence type, the most common interpretation within the adult group was identified. This response was then considered as the target. Each response by each participant was coded as the same or different relative to the target. A conformity index (CI) was then calculated for each participant for each sequence by calculating the proportion of trials on which the target response was selected. Analyses of group data were then conducted using a 4 (age)  $\times$  2 (length)  $\times$  3 (sequence type) mixed ANOVA, with age (preschool, school, teenagers, and adults) as a between subjects variable; and length (three or four symbols) and sequence type (canonical, verb initial, or verb final) as within subjects variables. The dependent variable was CI.

Second, individual patterns of responses for each length and sequence type were analyzed, based on two measures. The first measure evaluated consistency in assignment of the role of agent to the first or second noun for each sequence type and in assignment of the attribute to the preceding noun (in the four-symbol sequences). Participants were classified as consistent responders if they selected the same interpretation on 75% of the trials for a particular sequence type. The cut-off was set at a relatively high level (i.e., clearly above the chance level of 25% on this task), in order to allow a high level of confidence when classifying a participant as relying predominantly on a specific strategy. The second measure in the analysis of individual

patterns evaluated whether participants used the specific interpretation strategies that were preferred by adult participants (i.e., the target for each sequence type as identified in the analysis of group data above) and the presence of other strategies (if any).

Decisions regarding classification of participants (consistent or not; strategy use) were double-checked by a second research assistant. Agreement was above 95% for all age groups. These individual patterns were analyzed using descriptive statistics.

## **RESULTS**

### **Group Patterns**

Adult performance was used to determine the target response. For canonical sequences, adults were highly consistent. They chose the same strategy (N1 = agent) across three- and four-symbol sequences (98.8% and 99% of responses, respectively), and consistently assigned the attribute to the noun (N1 or N2) immediately preceding it (99.5%) in the four-symbol sequences. Therefore, target responses for canonical sequences were as follows: for NVN (C-3): the photo depicting the correct verb and N1 = agent; for NAVN (C-4): the photo depicting N1 = agent and the attribute assigned to N1; and for NVNA (C-4): the photo depicting N1 = agent and the attribute assigned to N2 (see Table 2).

On non-canonical sequences, adults consistently assigned the attribute to the noun immediately preceding it (99.3%), but patterns of agent-role assignment differed from those observed for canonical sequences. For verb-final sequences, adults chose N1 as agent on 74.6% and 58.8% of trials for three- and four-symbol sequences, respectively. For verb-initial sequences, they chose N2 as agent on 62.1% and 60.8% of trials for three- and four-symbol sequences, respectively. Thus the target responses for non-canonical sequences were as follows: for NNV (VF-3): the photo depicting the correct verb and N1 = agent; for VNN (VI-3): the photo depicting N2 = agent; for NANV (VF-4): the photo depicting the correct verb and N1 = agent and the attribute assigned to N1; and for VNNA (VI-4): the photo depicting N2 = agent and the attribute assigned to N2 (Figure 2).

A preliminary analysis showed that the two types of four-symbol canonical sequences could be collapsed into one category labeled Canonical (non-significant paired T-test,  $t(119) = -1.82$ ;  $p = 0.072$ ; mean CI 79.2 and 83.3, for NAVN and NVNA, respectively). A 4  $\times$  2  $\times$  3 mixed ANOVA was carried

TABLE 2 Preferred Adult Response, Mean Conformity Index (CI) (with Standard Deviation) for each Sequence and Age Group.

Sequence	Preferred adult interpretation	CI			
		Age group			
		Preschool	School-aged	Teenagers	Adults
Canonical sequences					
C-3 (N1VN2)	N1 agent	63.3 (29.9)	96.0 (8.5)	98.8 (2.3)	98.8 (3.3)
C-4 (N1VN2a)	N1 agent + N2 attribute	35.83 (23.5)	89.1 (25.3)	93.8 (19.6)	98.0 (4.6)
C-4 (N1aVN2)	N1 agent + N1 attribute	40.9 (23.9)	93.1 (17.0)	98.8 (3.8)	100 (0)
Non-canonical sequences					
VF-3 (N1N2V)	N1 agent	53.3 (21.5)	76.4 (27.3)	72.5 (39.3)	74.6 (36.8)
VI-3 (VN1N2)	N2 agent	44.2 (29.1)	28.7 (33.9)	65.0 (39.0)	62.1 (45.8)
VF-4 (N1aN2V)	N1 agent + N1 attribute	35.6 (27.8)	81.0 (28.4)	66.7 (38.7)	58.8 (41.0)
VI-4 (VN1N2a)	N2 agent + N2 attribute	31.3 (21.5)	23.6 (30.7)	65.8 (40.9)	60.8 (43.0)

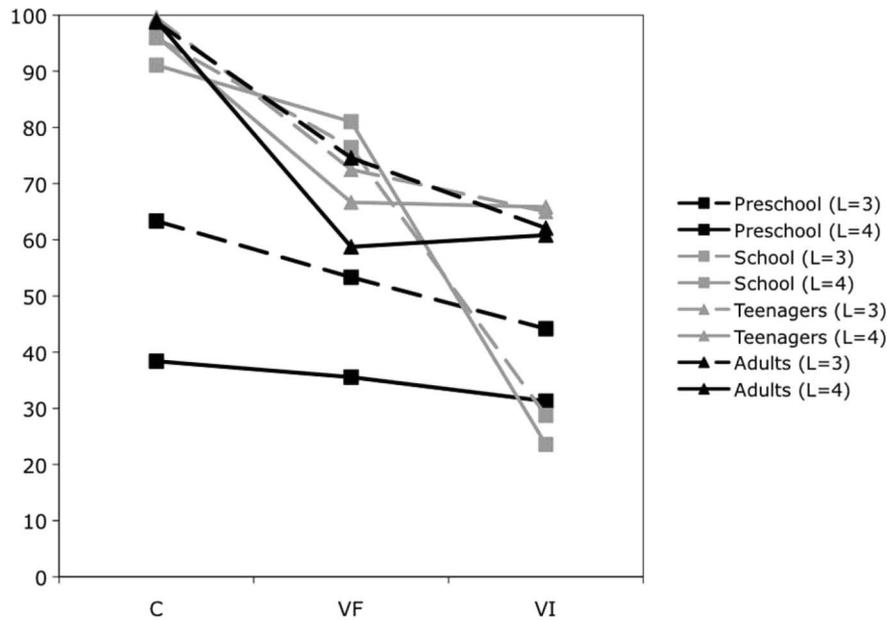


Figure 2. Mean Conformity Index for each sequence structure by age group. C, Canonical; VF, Verb-final; VI, Verb-initial; L, Length: three-symbol (3) or four-symbol (4) sequences.

out and revealed a main effect of age,  $F(3, 115) = 48.4$ ;  $p < 0.001$ . Post-hoc Tukey tests revealed that the CIs for preschool children were significantly lower (44.3) than for all other groups ( $p < 0.001$ ,  $d_{(\text{preschool/school})} = 1.27$ ,  $d_{(\text{preschool/teens})} = 1.96$ ,  $d_{(\text{preschool/adults})} = 1.84$ ). The school-aged children were also significantly different from all other groups (66.1), ( $p < 0.05$ ,  $d_{(\text{school/teens})} = 0.67$ ,  $d_{(\text{school/adults})} = 0.56$ ), but there was no significant difference between the teenagers and adults (mean CI = 77.6 and 75.7, respectively;  $p = 0.918$ ,  $d = 0.12$ ).

A main effect of sequence length was also observed,  $F(1, 115) = 23.4$ ;  $p < 0.001$ ; the mean CI was higher for 3-symbol sequences than for 4-symbol sequences (69.5 and 62.4, respectively). This effect was fairly small ( $d = 0.44$ ). The interaction of age  $\times$  length was significant,  $F(3, 115) = 6.81$ ,  $p < 0.001$ : the effect of length

was present in the youngest age group (mean CI = 53.6 and 35.1 for three- and four-symbol sequences, respectively), but all other differences between three- and four-symbol sequences were not significant (school-aged: 67.0 and 67.2; teenagers: 79.0 and 76.2; adults: 78.5 and 72.9; for three- and four-symbol sequences, respectively).

There was also a main effect of sequence type,  $F(2, 115) = 52.8$ ;  $p < 0.001$ . Pairwise comparisons revealed that mean CI was higher for canonical than for both of the non-canonical sequences, and within the non-canonical sequences the mean CI was higher for verb-final than for verb-initial sequences (85.3, 64.9; and 47.7 for canonical, VF and VI, respectively).

A significant age  $\times$  sequence type interaction was observed,  $F(6, 230) = 7.40$ ;  $p < 0.001$ , indicating that the effect of sequence type differed across the age groups. For the preschoolers, there

were no significant differences between the three sequence types (mean CI = 50.9, 44.4, and 37.7 for canonical, VF, and VI, respectively). The school-aged children's results mirrored the overall sequence-type main effect: mean CI was higher for canonical than for both non-canonical sequences, and, within non-canonical sequences, it was higher for VF than for VI sequences (93.5, 78.7, and 26.1 for canonical, VF, and VI, respectively). The teenagers and adults showed yet a different pattern; the mean CI was higher for canonical sequences (97.9 and 98.9 for teenagers and adults, respectively) than both non-canonical sequences (VF: 69.6 and 66.7; VI: 65.4 and 61.5, for teenagers and adults, respectively), but in the absence of a significant difference between the two non-canonical sequences. No other interactions were statistically significant.

These results show that sequence length affected performance of the youngest age group only. Furthermore, all groups relied on the same strategy for interpreting canonical sequences, but the school-age group performed differently from the teenagers and adults on the non-canonical sequences.

## Individual Patterns

### Consistency

The large majority of participants responded in a consistent fashion: the exception was the preschoolers when interpreting 4-symbol sequences

(see Table 3). On canonical sequences, the percentage of participants within a group who responded consistently increased from 77% for the pre-schoolers (3-symbol sequences only) to 91% of school-age participants and 100% of teenagers and adults (average of three- and four-symbol sequences, see Table 3).

Consistency of response patterns to non-canonical sequences showed a gradual increase across the age groups as well. Among preschoolers, only 65% interpreted the three-symbol non-canonical sequences in a consistent manner (average of VF-3 and VI-3 sequences), 17% responded consistently to VF-4 sequences, and none were consistent on the VI-4 sequences. By contrast, the average in the older groups for both three- and four-symbol non-canonical sequences was well above that of the pre-schoolers for three-symbol sequences (69%, 88%, and 90% for school-age participants, teenagers, and adults, respectively).

### Choice of strategy

Among the consistent responders, 70% of the preschoolers but 100% of school-aged, teenage, and adult participants assigned the agent role to the first noun (N1 = agent) on canonical sequences. However, the pattern of assignment of the agent role in the non-canonical sequences was quite different from that observed in canonical sequences. Among the adults, the strongest response preference was observed for the VF-3 sequence; adults assigned the agent role to the first

TABLE 3 Number of Participants (*n*) in each age Group using a Consistent Response Pattern for each Sequence Length, and Percentage of those Participants (%) choosing the First Noun (N1) as Agent.

Structure	Preschool ( <i>n</i> = 30)		School-aged ( <i>n</i> = 29)		Teenagers ( <i>n</i> = 30)		Adults ( <i>n</i> = 30)		
	Consistent	N1 = ag	Consistent	N1 = ag	Consistent	N1 = ag	Consistent	N1 = ag	
Canonical									
C-3	<i>n</i>	23	16	28	28	30	30	30	30
	%*	77	70	93	100	100	100	100	100
C-4*	<i>n</i>	7	5	26.5	26.5	29.5	29.5	30	30
	%	23	70	88	100	98	100	100	100
	Mean %	50	70	90.5	100	99	100	100	100
Non-canonical									
VF-3	<i>n</i>	19	11	19	18	28	22	28	22
	%	63	58	63	94	93	79	93	79
VF-4	<i>n</i>	5	4	22	21	24	17	27	16
	%	17	80	73	95	80	71	90	59
	Mean VF %	40	69	68	94.5	86.5	75	91.5	69
VI-3	<i>n</i>	20	11	21	17	27	7	27	10
	%	67	55	70	81	90	26	90	37
VI-4	<i>n</i>	0	NA	21	17	27	7	28	11
	%	0	NA	70	81	90	26	93	39
	Mean VI %	33.5		70	81	90	26	91.5	38
Mean % 3-symbol		65	56.5	66.5	87.5	91.5	52.5	91.5	58
Mean % 4-symbol		8.5	NA	71.5	88	85	48.5	91.5	49
Mean % overall		36.75	NA	69	87.75	88.25	50.5	91.5	53.5

noun. The three younger groups showed the same preference, which was, in fact, stronger among school-age children than among teenagers and adults (58%, 94%, 79%, and 79% for preschoolers, school-aged, teenagers, and adults, respectively). For the VF-4 sequence, preference for N1 = agent actually decreased from 95% in the school-age group to 71% and 59% for teenagers and adults, respectively. For VI sequences, there was a shift in strategy across the age groups. Preschoolers were divided between the two interpretations (55% preferred N1 as agent). School-age participants interpreted the first noun as agent (81% on both VI-3 and VI-4), but teenagers predominantly interpreted the second noun as agent (74% on both VI-3 and VI-4), in line with the adults' more moderate preference for the second noun as agent (63% on VI-3 and 61% on VI-4, respectively). Among the participants who responded in a consistent manner, the assignment of the attribute to the preceding noun was at ceiling.

## DISCUSSION

The goal of this study was to explore the use of word order strategies in the interpretation of graphic-symbol sequences, and determine if performance would differ across age groups for different utterance lengths and across canonical and non-canonical sequences. The Competition Model framework was used to hypothesize different possible word-order strategies that could be used in interpreting graphic-symbol sequences. In order to maximize dependency on word order, a paradigm was developed where all other potential cues (e.g., animacy, agreement, prosodic, contextual, and interactional) were reduced to a minimum. The results allow us to conclude with considerable evidence that word order can be used as a cue to the interpretation of sequences of graphic symbols by individuals with no prior experience using AAC and who have not received explicit instruction in how to interpret graphic symbol sequences. Moreover, the reliance on word-order strategies increased with age. Regarding the effect of length, the response patterns indicate that preschoolers used word order in interpretation of graphic symbol sequences, but only for shorter (three-symbol) and not for longer (four-symbol) sequences, whereas older participants were not influenced by the length of the sequences. As for the specific type of sequence presented, canonical, verb-initial, and verb-final sequences elicited different response patterns that also differed across age groups. While pre-school children showed a weaker preference for specific interpretations,

school-age children applied the same interpretation strategy (N1 = agent) to all sequence types, irrespective of canonicity. Teenagers' response patterns were similar to those of adults with respect to the general preference to assign the agent role to N1 in canonical and verb-final sequences and to N2 in verb-initial sequences. All of these findings are compatible with the strategies proposed within the Competition Model framework.

## Developmental Trends

As predicted, the participants from different age groups responded differently. The factors that influenced their performance varied across age group, as did the specific strategies used to interpret specific types of sequences.

Length was a primary determinant of younger children's performance: Well over half of the preschoolers interpreted three-symbol sequences in a consistent manner, but only a few responded consistently to four-symbol sequences. Even when word order would be a sufficient and valid cue to interpret symbol sequences (i.e., in the case of canonical sequences), the youngest children did not always use it in their interpretations. This could be due to a difficulty in transferring a strategy across modality (i.e., from auditory to visual), or it may be that the presentation of a visual stimulus leads children to entertain strategies drawn from experience in the visual modality. They might, for example, consider the symbol sequence together, as parts of a drawing representing a scene, rather than a sequence of individual symbols regulated by some ordering rules. Alternatively, the presentation of three items may represent a threshold beyond which preschool children can no longer process the amount of information or the multiple permutations possible. Within the framework of the Competition Model, it appears that word order has too high a cost for it to be used by young children for sequences of four symbols. This finding suggests that if young children were to successfully interpret four-symbol sequences in real-life interactions, they would need to tap into other types of cues, most likely contextual. In other words, in a setting where the only cue available to the children is word order, the task of interpreting four-symbol sequences is too difficult, resulting in random responding by most. This is clearly not the case for older participants whose response patterns were similar across the two sequence lengths.

The nature of the graphic symbol sequences (canonical versus non-canonical) also played an important role. When presented with sequences that conformed to the canonical order of their spoken language, the youngest participants

demonstrated the ability to apply their knowledge of word order to the interpretation of graphic symbol sequences that were short. The majority of preschoolers assigned the agent role to the first noun in an NVN sequence, consistent with studies of spoken language production and comprehension demonstrating early sensitivity to word order (Akhtar, 1999; Dittmar et al., 2008; Gertner et al., 2006; Vion & Amy, 1984). However, not all preschoolers who responded consistently used canonical word order: A few preschoolers consistently selected the second noun as the agent. This indicates that sensitivity to sequential order (i.e., the use of a consistent response pattern) may precede the ability to transfer experience with a specific word order across task or modality (i.e., the use of the French word order). Furthermore, it appears that sensitivity to specific word orders may emerge before children can overcome the length constraint, as the few children who did respond consistently to four-symbol sequences were even more likely to use canonical word order than the children who responded consistently to three-symbol sequences. By school-age, participants who responded consistently all used the same strategy. All participants at this age or older relied on the canonical order of their spoken language to assign the agent and patient roles (cf. Sutton & Morford, 1998, for English speakers). Furthermore, in their responses to four-symbol sequences, all participants of school age or older assigned the attribute to the preceding noun, showing sensitivity to the French noun-attribute pattern.

Presenting non-canonical sequences did not deter some preschoolers from using a stable interpretation of three-symbol graphic sequences: The probability of consistent responding was almost as high for non-canonical as for canonical sequences. Sequence type however, did appear to affect the choice of which particular strategy would be used. N1 = agent was the predominant response to canonical sequences; in contrast, equal numbers of participants selected N1 = agent and N2 = agent interpretations of the non-canonical sequences. This finding is consistent with the patterns observed in 2- and 3-year-old Italian-speaking children, as well as 3- to 5-year-old English-speaking children (Slobin & Bever, 1982) who, as a group, also responded at chance level when presented with VNN and NNV spoken sentences. Again, the evidence points to a strong sensitivity to linear sequence, possibly superseding a reliance on a specific word order.

In all other groups, fewer participants responded consistently to non-canonical than canonical sequences, an indication that participants may have struggled to identify a useful strategy to deal with these unfamiliar structures.

Several possible explanations for the observed patterns arise from the data, based on aspects of the participants' linguistic experience that could contribute to constructing such interpretations. School-age participants interpreted the N1 as agent for both verb-final and verb-initial non-canonical utterances, as predicted by the FM strategy (see Table 1), and consistent with Kail and Charvillat's (1988) findings for this age group in an act-out task. A reasonable interpretation of the performance of the school-age group is that they automatically interpreted the first noun encountered as the agent, a cue that is consistent with their knowledge of canonical order in French, but that does not require the sequence as a whole to be considered prior to role assignment. This pattern is consistent with the Competition Model framework, in that it reveals a general application of a rule, based on a salient and valid cue under normal circumstances. The expected developmental pattern would be to continue applying that valid cue, but with more nuances, based on further exposure to language and improved competence.

Teenagers and adults were mixed in their choice of N1 and N2 as agent for the non-canonical sequences, but the tendency was to interpret N1 as agent for verb-final sequences and N2 as agent for verb-initial sequences. This pattern is most consistent with the LFS strategy (see Table 1). Additional support for the view that the older participants may have relied on less frequent spoken-language structures is the fact that there was more agreement among participants for the verb-final sequences, which occur more frequently than verb-initial sequences in spoken French (Kail, 2004). Some participants at each of these ages persisted in interpreting N1 as agent for all sequence types. Thus, the FM strategy may compete with alternative, and more cognitively costly strategies, among the older participants.

Taken together, the data suggest a shift across development in the type of word order strategy used to interpret non-canonical sequences. Younger participants were more likely to select a strategy such as first mention, which has a low cue cost. This finding supports the notion that once children have identified word order as a reliable strategy for interpretation of spoken French, they can apply that strategy to other symbolic domains, such as graphic-symbol sequences, but that they do so in a mechanistic way (i.e., by adhering to a salient characteristic of word order, such as initial position in the sequence, without regard to the relationship of other units within the sequence to each other). This is not unlike what Bates et al. (1984) reported in their study of Italian children.

Increased experience with a range of grammatical constructions allows participants to incorporate knowledge of less common linguistic structures into their interpretation of graphic symbol sequences, resulting in different analyses across symbol orders. This evolution from applying one strategy to all structures to using alternate strategies for different structures is reminiscent of what Lempert and Kinsbourne (1980) called increased flexibility. They observed flexibility in 5- and 6-year-olds' interpretation of oral sentences, whereas the current data suggests that flexibility may come later, when transferring that knowledge to the graphic modality. Indeed, most 7- and 8-year-olds in the current study did not show the ability to change strategy when interpreting different sequences.

Thus, there appears to be an evolution from random responding and equal value of different strategies (3- and 4-year-olds) to the use of a single strategy (N1 = agent; 7- and 8-year-olds), followed by the use of several strategies within the group and greater variation in the choice of specific strategies by individuals. Moreover, with increasing linguistic experience, participants' use of word order information to interpret graphic-symbol sequences may reflect sensitivity to the constituent relations driving those word order patterns.

### Theoretical and Clinical Implications

This study extends previous work on the interpretation of utterances based on word order. Interpretation of graphic symbol sequences offers an original way to look at theoretical issues surrounding the use of word order as a cue in sentence interpretation. The findings suggest that strategies observed in interpretation of spoken word order are also applied to utterances composed of graphic symbols. However, spoken language knowledge does not automatically or effortlessly transfer to interpretation of graphic symbol utterances, especially early in development. The 3- and 4- year-olds showed tremendous difficulty in interpreting even very simple sequences that were clearly within their reach orally (see Sutton et al., 2010, for a more detailed analysis of both production and comprehension in this age group). Therefore, one should not use comprehension of graphic symbol sequences as a direct measure of an individual's competence in a spoken language. This corroborates and extends earlier work with English speakers showing this same effect (Smith, 1996; Sutton & Morford, 1998).

The current results also reveal how language knowledge may gradually transfer to AAC system usage, at least in a highly controlled experimental setting. If reliance on word order is still strong in

real life interactions, it could be seen either as a benefit or as a liability. For seasoned AAC users, predicting the way that their symbol sequences will be interpreted would be somewhat easier when they are conversing with older partners. However, for less proficient users whose production may be less canonical, older partners' spoken-language expectations may sometimes interfere with understanding the actual message.

Replication of this study with people who actually use AAC, and investigating the effects of age, language proficiency, and experience with AAC systems would help clarify some of these issues. Based on the current data, it seems that successful implementation of an AAC system should not only involve training for the person using the system (i.e., helping them achieve an output that is easily interpreted) but also should rely on some training of the communication partners (i.e., to ensure that their interpretation is in tune with the strategies used to produce the message). On-line adjustments in interpretation and production strategies may be needed, depending on the strategies employed by the "speaker" and the "listener", calling for intervention approaches that go beyond the linguistic aspects of communication to include metalinguistic and pragmatic skills of both communication partners.

As mentioned previously, real-life interactions are usually much richer in terms of potential cues that are available to interpret utterances. From that perspective, further studies are needed to consider how word order is weighed against these other cues in more naturalistic communicative exchanges using graphic symbol sequences. In such contexts, other theoretical frameworks, such as Grice's maxims of conversation (1975), or Sperber and Wilson's (1986) maximizing relevance principle, may prove useful in expanding the perspective offered by the Competition Model.

### Acknowledgements

This research was funded by the Social Sciences and Research Council of Canada. The writing of this article was also supported in part by NSF Grant SBE-0541953 to establish the Science of Learning Center for Visual Language and Visual Learning (VL2). Parts of the data were presented at the International Society for Augmentative and Alternative Communication conference in Düsseldorf, Germany, in August 2006, and at the American Speech-Language-Hearing Association conference in Boston in November 2007. The authors thank all the participants in the study, as well as Monica Rios, Marie-Andrée Poirier, Sophie de Broeck, Virginie Isquin, Valérie Legault, Anne-Marie Pauzé, and Josée Goyer who collected the data.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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