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Research article

Constituent order in silent gesture reflects the perspective of the producer

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Abstract

Understanding the relationship between human cognition and linguistic structure is a central theme in language evolution research. Numerous studies have investigated this question using the silent gesture paradigm in which participants describe events using only gesture and no speech. Research using this paradigm has found that Agent–Patient–Action (APV) is the most commonly produced gesture order, regardless of the producer's native language. However, studies have uncovered a range of factors that influence ordering preferences. One such factor is salience, which has been suggested as a key determiner of word order. Specifically, humans, who are typically agents, are more salient than inanimate objects, so tend to be mentioned first. In this study, we investigated the role of salience in more detail and asked whether manipulating the salience of a human agent would modulate the tendency to express humans before objects. We found, first, that APV was less common than expected based on previous literature. Secondly, salience influenced the relative ordering of the patient and action, but not the agent and patient. For events involving a non-salient agent, participants typically expressed the patient before the action and vice versa for salient agents. Thirdly, participants typically omitted non-salient agents from their descriptions. We present details of a novel computational solution that infers the orders participants would have produced had they expressed all three constituents on every trial. Our analysis showed that events involving salient agents tended to elicit AVP; those involving a non-salient agent were typically described with APV, modulated by a strong tendency to omit the agent. We argue that these findings provide evidence that the effect of salience is realized through its effect on the perspective from which a producer frames an event.

Key words: word order; salience; silent gesture; animacy; perspective

1. Introduction

How do people convey information about events in the absence of linguistic conventions? This is one of the central questions in language evolution research, and answering it can shed light on the biases and pressures that shape emerging languages. Over the past decade, a number of studies have investigated this question using the silent gesture paradigm in which participants describe events using only gesture and no speech. In one of the earliest studies of this kind, Goldin-Meadow et al. (2008) found that speakers of different languages (Chinese, English, Spanish, and Turkish) expressed event constituents in an order the authors classed as consistent with Agent–Patient–Action (APV), irrespective of their native language. Similar findings were reported in a later study involving Italian- and Turkish-speaking participants (Langus and Nespor 2010). To explain their findings, Goldin-Meadow et al. (2008) argued that concrete entities are cognitively more basic than actions and so tend to be mentioned first. In addition, they hypothesized a close cognitive link between the patient and action such that they tend to be mentioned contiguously, yielding APV. Going further, the authors drew a parallel between APV and Subject–Object–Verb (SOV) and proposed that this is the default order used by all newly developing languages.

Studies of young sign languages, however, challenge this view. de Vos and Pfau (2015), for example, conducted a review of young rural sign languages and found no evidence that they share a single, preferred constituent order. In addition, a growing body of silent gesture literature has uncovered numerous factors that influence improvised word order. These include the semantic relation between interacting entities (Schouwstra and de Swart 2014), the temporal properties of events (Christensen et al. 2016; Gershkoff-Stowe and Goldin-Meadow 2002), the animacy of interacting entities (Futrell et al. 2015; Gibson et al. 2013; Hall et al. 2013, 2014; Kocab et al. 2018; Meir et al. 2017), and even the availability of a lexicon (Hall et al. 2014; Marno et al. 2015).

In a recent study investigating the relationship between animacy and word order in silent gesture and emerging sign languages, Meir et al. (2017) argued that SOV is no more cognitively basic than any other order. Rather, they suggest that word order in emerging languages reflects the relative salience of interacting entities. Specifically, they propose that human referents are more salient than inanimate entities and therefore tend to be mentioned first.[1] This 'human-first' principle is supported by findings from both emerging sign languages (Nicaraguan Sign Language: Flaherty 2014; Central Taurus Sign Language: Ergin et al. 2018) and language production studies (e.g., Prat-Sala and Branigan 2000; van Nice and Dietrich 2003; Branigan et al. 2008; Dennison 2008; van de Velde et al. 2014; Esaulova et al. 2019), which have found that people tend to use constructions in which animate entities are expressed before inanimate entities.

But what exactly is meant by the term 'salience'? For Meir et al. (2017), the salience of human entities derives from the central importance of conspecifics to human cognition. Elsewhere, the term has been applied to a range of phenomena that can be broadly summarized as referring to factors that make an entity more prominent, important, or interesting, and therefore more likely to attract the attention of the viewer (Ferreira and Rehrig 2019).[2] Accordingly, the salience of a referent may derive not only from conceptual properties such as animacy, but from numerous other factors including discourse prominence (e.g., Prat-Sala and Branigan 2000), visual properties such as size, contrast, or colour (e.g., Coco et al. 2014; Clarke et al. 2015), or visually drawing a speaker's attention towards a particular referent (e.g., Gleitman et al. 2007; Myachykov and Tomlin 2008; Myachykov et al. 2012; Vogels et al. 2013; Antón-Méndez 2017). The general conclusion from these studies is that more salient entities tend to be mentioned earlier (but see Myachykov et al. 2009; Hwang and Kaiser 2015, for evidence of language-specific differences that modulate the effect of visual cueing).

In this study, we investigated in more detail the relationship between salience and word order in communication systems that lack linguistic conventions. An important question concerns whether salience deriving from one property, such as animacy, can interact with salience based on another in influencing word order. Here, we asked if the human-first bias can be modulated by manipulating the contextual salience of entities in an event. Evidence from a small number of language production studies suggests that animacy-based salience can indeed be modulated, or overridden. For example, in a verbal sentence production task involving English- and Spanish-speaking participants, Prat-Sala and Branigan (2000) found that making an inherently non-salient entity, such as an inanimate object, more salient in discourse could override the preference for expressing animate entities earlier. In a more recent study in which English-speaking participants provided written responses, Rissman et al. (2018) found that reducing the visual prominence of a human agent by occluding the face resulted in significantly more passive descriptions

1 The authors only consider the distinction between human and inanimate entities, since their elicitation material did not include referents in other categories, for example, animate non-humans.

2 Ferreira and Rehrig (2019) note that in the scene literature, 'salience' refers to measurable, low-level visual properties such as luminance and size. In the psycholinguistics literature, the term is applied more loosely. In this study, we use the term in this less formal sense as a terminological convenience. Salience has also been equated with the notion of conceptual accessibility, which refers to the how 'thinkable' a concept is and how easily it is retrieved from memory (Bock and Warren 1985).

(i.e., the inanimate patient was mentioned first), compared with events in which the face was visible. In this study, we extended the scope of this approach by investigating the influence of contextually derived salience in silent gesture.

Previous studies in the silent gesture literature have not taken into account how the salience, or interestingness, of a human agent might influence word order choices. While some have used elicitation stimuli involving generic humans such as a man or a woman (e.g., Hall et al. 2013), others have featured more salient characters, such as a pirate or ballerina (e.g., Schouwstra 2012; Christensen et al. 2016), or a mix of generic and character agents (e.g., Goldin-Meadow et al. 2008; Langus and Nespor 2010; Gibson et al. 2013). In addition, inanimate patients have typically been small with respect to the human agent (e.g., a guitar, ball, food item, plant). This may have maximized the salience difference between the agent and patient by combining a size/visual prominence contrast (Clarke et al. 2015) with the animacy distinction. In this study, we sought to eliminate the effects of size by using inanimate patients of a similar size and scale to the agents, making it easier to focus our investigation on the influence of agent salience.

The study had two main objectives. First, we sought to replicate the APV[3] ordering preference in a silent gesture study in which participants described simple transitive events involving human agents and concrete, inanimate patients. Secondly, we investigated if manipulating the salience of a human agent influenced word order choices.

In the silent gesture experiment detailed in the next section, we asked participants to describe simple transitive events involving human agents and inanimate patients. We manipulated the salience of the agents across two conditions such that participants described events involving either a 'generic' human, such as a man or a woman, or a more interesting character, such as a king or a pirate (see Section 2.2 for more details). The hypothesis we sought to test was that the tendency to express human agents before inanimate patients would be modulated by manipulating the salience of the agent. Both spoken and sign languages offer devices for backgrounding non-salient agents. For example, the passive form in English allows speakers to mention the patient before the agent, or to omit the agent entirely. Agent omission is also frequently used in sign languages as a backgrounding device (e.g., American Sign Language: Kegl 1990; Janzen et al. 2001; Catalan Sign Language: Barberà et al. 2018; Nicaraguan Sign Language: Rissman et al. 2020). The focus of this study was to investigate the proposal by Meir et al. (2017) that salience influences word order. Accordingly, we predicted that reducing the salience of the agent, presented along with a large, visually prominent patient, would lead to fewer APV responses, and correspondingly more PAV.

To pre-empt our results, we found that, across the board, APV was less common than we anticipated and that PAV was rare. In addition, the relative ordering of the patient and action was strongly dependent on event type such that patients tended to precede actions for generic-agent events and vice versa for events involving character agents. A third key finding was that participants showed a strong tendency to omit generic agents, but not character agents, from their descriptions. We will argue that, taken together, these findings provide evidence that salience influences structural choices through its effect on the perspective from which the producer frames an event.

As noted above, omitting referents, particularly agents, is a common feature of sign languages. This phenomenon is also found frequently in silent gesture studies (e.g., Goldin-Meadow et al. 2008). While many studies have simply excluded incomplete orders from the analysis (e.g., Christensen et al. 2016), others have incorporated them by classifying them as consistent with a complete order according to some criterion, such as the relative positioning of the expressed constituents (e.g., Goldin-Meadow et al. 2008; Gibson et al. 2013; Hall et al. 2013). In Section 3, we present an alternative solution: a computational model that exploits incomplete descriptions of events to infer the distribution of word orders that participants would have produced had they expressed all three constituents on every trial. This analysis suggests that in this study APV was the preferred order for describing generic-agent events, and AVP was preferred for character-agent events.

3 It is common practice in the silent gesture literature to equate agents with subjects and patients with objects, ostensibly as a notational convenience. We do not follow this convention, since we make no assumptions about the syntactic status of gestured descriptions. In this study, we coded gestures according to the semantic role of referents. We used 'A' for agent, 'P' for patient, and, to avoid confusion with agent, 'V' for action.

2. Experiment 1: silent gesture task

2.1 Participants

We recruited twenty-eight participants via the University of Edinburgh's Career Hub website. All participants were self-reported native English speakers with no knowledge of any sign language. They were paid £5 for their participation in the experiment.

2.2 Materials

The stimuli consisted of a set of cartoon images depicting simple transitive events. Stimuli were controlled for animacy such that all events involved a human agent acting on an inanimate patient. To control for effects of concreteness, or the semantic relation between interacting entities, all events were *extensional*; that is, both the agent and patient were concrete entities existing independently of the action (Schouwstra and de Swart 2014).

We produced two sets of stimuli depicting either generic agent or character agent events. Generic agent events involved human agents that were identifiable by gender or could be described with reference to basic physical characteristics such as facial hair, glasses, or other accessories. Character agents were strongly associated with a profession and/or a distinctive cultural identity, for example, a king or a pirate. We expected that character agents would have high salience due to their distinctive and prominent physical features (e.g., a pirate with an eye patch and bandanna), and to their being less prototypical representations of humans. All events depicted the same set of inanimate patients. To control for ordering effects based on the relative size of referents (Clarke et al. 2015), all patients were designed to be similar in size and scale to the agents. The full set of stimuli consisted of five character humans, five generic humans, four objects, and four actions (see Appendix A). This gave eighty character agent events and eighty generic agent events. Figure 1 shows an example of (1) a generic agent event and (2) a character agent event.

2.3 Procedure

Participants were randomly assigned to one of two conditions. In the generic-first condition, they were first presented with a block of forty generic agent events followed by a block of forty character agent events. In the character first condition, the order of presentation was reversed.[4] Items were presented in pseudo-random

Figure 1 Example items showing (**a**) a generic-agent event and (**b**) a character-agent event.

order such that consecutive trials differed in all three constituents. A different pseudo-randomly ordered set was generated for each participant. The left-to-right arrangement of the agent and patient was randomized across trials. Participants were presented with written instructions asking them to describe each scene using only gestures. They were further instructed to not speak and to provide as much information as they could. Participants were not cued to the kind of information they were expected to produce (i.e., there was no explicit mention of APV).

Prior to each testing block, participants completed a passive exposure phase in which they were shown ten randomly selected events simultaneously. The event type (generic or character) depicted in the scenes corresponded to the block event type. Participants were provided with written instructions requesting that they pay close attention to the details of each scene and think about what the scenes had in common and how they differed. The purpose of this exposure phase was to prompt participants to notice that scenes contained different interacting entities and actions, and thereby encourage them to express all three constituents without providing an explicit cue to this effect.

Previous studies where participants were explicitly instructed to provide three gestures were not successful in preventing omissions (e.g., Langus and Nespor [2010] found that approximately 40% of responses contained two gestures). Moreover, this approach is, in our view, too informative as to the nature of the task (Schouwstra 2012). An alternative strategy would be to use a director-matcher design, where one participant communicates about an event to a partner whose task is to identify the target event from a set of options. While this approach has been used in some silent gesture studies

4 Given our definition of salience, that is, how interesting or prominent an entity is, it is not clear how this would be affected by mixing event types. On the one hand, presenting generic agents with character agents might make them more salient because of the contrast. Alternatively, they may become even less salient when contrasted with the more interesting characters. Given this uncertainty, we felt it was more appropriate to present the two event types separately.

(e.g., Christensen et al. 2016; Meir et al. 2017), we chose not to adopt it, since contrasting the target agent against alternatives within a trial might have the effect of increasing its contextual salience. In addition, the effect of introducing a communicative pressure is not clear. There is some suggestive evidence that it may influence the word orders people use (e.g., Hall et al. 2015) and drive them to be more consistent in their choices and less improvizational (Schouwstra et al. 2020, preprint).

Participants completed the experiment seated alone in a booth. Stimuli and instructions were presented on a computer screen, and responses were video recorded using a webcam. The experiment was developed using PsychoPy (Peirce 2009).

2.4 Coding

Individual gestures within a sequence were coded according to the intended referent—APV. On a number of trials, participants also encoded the result of the action, for example, by indicating an object falling. These result gestures ('R') were excluded from the analysis (see below). As is common practice in the gesture literature, multiple consecutive gestures with the same referent were coded as a single constituent (e.g., Hall et al. 2013; Meir et al. 2017; Kocab et al. 2018). All gestures in a given trial were coded as a single utterance except where the participant returned to a neutral position for more than 2 s before resuming their response. In these cases, multiple responses were recorded.

Two data cleaning procedures were applied. First, contiguous repeated sequences were replaced with a single occurrence of the sequence. For example, the string APAPV was recoded as APV. This decision was motivated by the observation that some participants appeared to repeat sequences as a way of filling thinking time. There were 57 such trials (5.2% of 1104 trials). Secondly, result gestures were removed from the sequence, since we were primarily interested in the relative ordering of the APV. This included 'R' gestures as well as 'PR' sequences where the patient was expressed earlier in the string. For example, APVPR was recoded as APV. This decision was based on the assumption that the participant reintroduced the patient to provide context for the result gesture. In total, 216 (19.6%) responses contained an 'R' gesture, of which 36 (3.3%) were part of a 'PR' sequence.

Following these data cleaning procedures, responses were recoded for analysis as follows: (1) strings containing one or more simultaneously produced gestures were coded *simultaneous*. There were fifty (4.5%) such trials; (2) for trials in which multiple responses were recorded, we retained the first sequence that contained the action and at least one occurrence of a noun referent. There were two (<1%) such trials—in both, the retained sequence was the first of two; (3) following Hall et al. (2013), orders that individually accounted for <2% of trials were coded *rare*. A total of 88 (8.0%) trials fell into this category.

2.5 Results

Nine trials were excluded from the analysis due to a technical error, and a further seven were excluded because the participant did not provide a response. The resulting dataset comprised 1104 trials (557 character-agent trials and 547 generic-agent trials).

In the sections that follow, we first investigate the overall proportion of responses coded as APV for each agent type. We then present a more detailed analysis of the results from each block.

2.5.1 Proportion of responses coded as APV

Figure 2 shows the distribution of word orders for each agent type across both blocks. It represents 557 character-agent events (278 from block 1; 279 from block 2) and 547 generic-agent events (280 from block 1; 267 from block 2).

Contrary to our expectations, we found no evidence that APV was the preferred order, although it was one of the most commonly used. This finding is at odds with previous studies; we return to this in Section 2.6. Participants produced APV on 25.3% of trials overall (24.1% of character-agent trials; 26.5% generic-agent). In addition, we found that AVP was used exactly as often as APV, accounting for 25.3% of trials overall (24.2% character-agent; 26.3% generic-agent).

The equal preference for APV and AVP was reflected at the participant level. Out of twenty-eight participants, eight used AVPs as their most common order overall across both blocks and nine used APVs (seven as their most common order and two jointly with one other order). We found a similarly even distribution across agent types (see Table 1).

2.5.2 Block 1

Figure 3 (left) shows the distribution of word orders in block 1 plotted by agent type. The results are summarized in Table 2. As we noted above, the overall proportion of APV trials was unexpectedly low. In block 1, the proportion was lower still at 15.8% (13.3% of character-agent trials; 18.2% of generic-agent trials). Looking at individual responses, only five of the twenty-

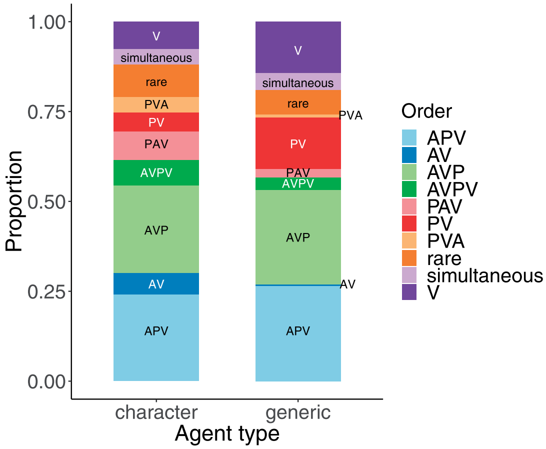

Figure 2 Word orders used to describe character-agent events and generic-agent events across both blocks. We found no evidence that APV was the preferred order. APV and AVP were the most frequent orders and occurred in roughly equal proportions.

Table 1 Number of participants who used APV or AVP as their most common order overall across blocks, and by agent type.

Word order	Number of participants		
	Overall	By agent type	
		Character	Generic
APV	9	7	9
AVP	8	9	8

eight participants used APV most often, or as often as another order in the first block (Fig. 4, top row; counts for each condition and block are summarized in Table 3).

Cells in normal font indicate character-agent trials; cells in boldface show generic-agent trials.

We also found that PAV was rare for both types of event (1.4% of character-agent events; 3.2% of generic-agent events). Recall, however, that our main prediction was that participants would express generic agents before the patient less often than character agents. To investigate this, independent of the positioning of the action, we analysed all trials for which it was possible to determine the relative positioning of the agent and patient. Trials in which one or both noun referents were omitted or where they were expressed simultaneously were therefore excluded. On some trials, participants expressed the agent or patient more than once. We categorized such responses according to the position of the first occurrence of each constituent. The resulting dataset included 317 trials (213 character-agent and 104 generic-agent trials).

For both types of agent, participants expressed the agent before the patient in a majority of trials (80.8% of character-agent events; 87.5% of generic-agent events; see Fig. 5). A mixed-effects logistic regression analysis[5] found no significant difference between agent types (Table 4).

Nevertheless, Fig. 3 clearly suggests that responses were indeed affected by the agent. Events depicting character agents were predominantly described using AVP (36.3% of responses). In contrast, this order was rare for generic-agent events (5.4%). Looking at individual responses, while seven people used AVP most often to describe character-agent events, only one used this order most frequently to describe generic-agent events (see Table 3).

Descriptions of generic-agent events were characterized by a high proportion of incomplete orders, that is, orders in which one or more constituents were omitted. Across all trials, 62.9% of generic-agent trials in block 1 elicited an incomplete order compared with 23.4% of character-agent trials. PV and V accounted for the majority of incomplete descriptions of generic-agent events, indicating that generic-agent omissions were more common than patient omissions.

Agent and patient omissions for each agent type are plotted in Fig. 6. A mixed-effects logistic regression analysis confirmed that participants were significantly more likely to omit generic agents (62.1% of trials) compared with character agents (16.5%) (see Table 5). We suggest that this reflects the lower salience of generic agents compared with character agents.

Patient omissions were also more frequent for events depicting generic agents (28.6%) compared with character-agent events (14.8%). However, this difference was not significant (Table 6). The model additionally showed that there was a significant interaction between agent type and image orientation. A possible explanation for this finding is that left-positioned patients are more prominent than patients positioned to the right of the agent (e.g., Esaulova et al. 2019). This effect may have been greater when the agent had low salience (i.e., a generic agent) and was therefore less likely to compete with the patient for the viewer's attention.

One possible explanation for why AVP responses were rare for generic-agent events is that this was a

5 All analyses in this study were performed using the R programming language (R Core Team 2017) and the *lme4* package (Bates et al. 2015).

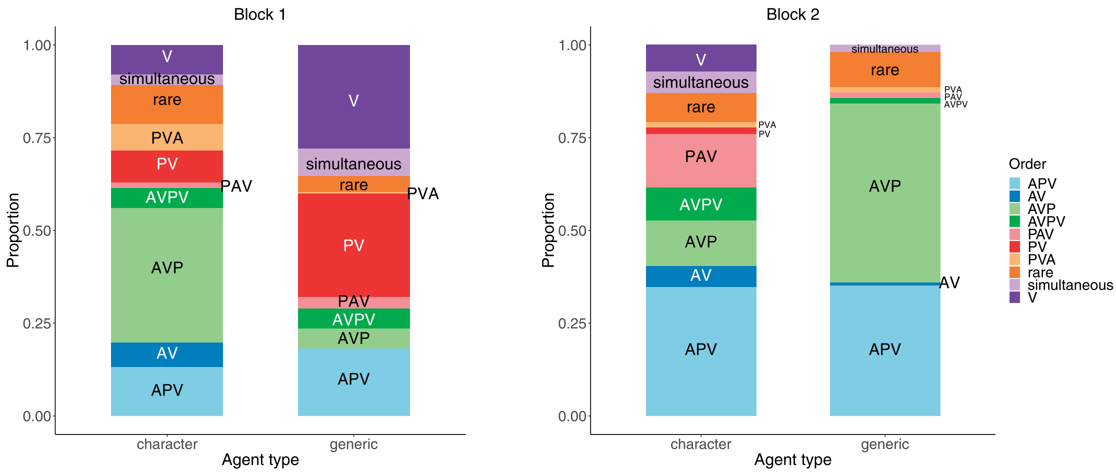

Figure 3 The distribution of word orders by agent type in block 1 (left) and block 2 (right). These plots demonstrate that structural choices were sensitive to agent type.

Table 2 Word order proportions in each condition and block.

Word order	Character-first		Generic-first	
	Block 1	Block 2	Block 1	Block 2
APV	0.133	**0.352**	**0.182**	0.348
AV	0.065	**0.007**	**0.000**	0.057
AVP	0.363	**0.483**	**0.054**	0.122
AVPV	0.054	**0.015**	**0.054**	0.090
PAV	0.014	**0.015**	**0.032**	0.143
PV	0.086	**0.000**	**0.279**	0.018
PVA	0.072	**0.015**	**0.004**	0.014
V	0.079	**0.000**	**0.279**	0.072
Simultaneous	0.029	**0.019**	**0.075**	0.057
Rare	0.104	**0.094**	**0.043**	0.079

Cells in normal font indicate character-agent trials; cells in boldface show generic-agent trials.

straightforward consequence of participants omitting the agent. However, a more detailed analysis of the data suggests that this is unlikely to be the case. Specifically, we found that participants were significantly more likely to express the patient before the action when describing generic-agent events (78.5% of trials) compared with character-agent events (46.7%). Details of the statistical analysis are provided in Table B.14 (Appendix B). This demonstrates that there was not only a significant difference in the rate of agent omissions, but also in the relative ordering of expressed constituents. In addition, as we will see in Section 3, the results of the computational model indicate that the majority of incomplete descriptions of generic-agent events derived from an underlying APV order rather than AVP.

2.5.2.1 Block 1 discussion. We can draw two general conclusions from the analysis of block 1 responses. First, as in the combined analysis, we found no evidence to support the claim that APV is the preferred order for describing events involving an animate agent and an inanimate patient (cf. Goldin-Meadow et al. 2008). Secondly, although the results did not support the hypothesis that generic-agent events would elicit fewer agent-before-patient responses compared with character-agent events, we found that structural choices in block 1 were clearly conditioned on agent type. AVP was the preferred order for character-agent events, but was rare for generic-agent events. For this type of event, participants showed a strong tendency to omit the agent, which we attribute to their lower salience. Among trials in which at least one noun referent was expressed, PV was the most common order for generic-agent events.

2.5.3 Block 2

In block 2, we saw an increase in the proportion of APV responses for both types of event. This order accounted for 35.0% of trials overall in block 2 (15.8% in block 1): 34.8% of character-agent trials and 35.2% of generic-agent trials (see Table 2). Although this increase did not reach statistical significance (see Table 7), it is nevertheless notable that the number of participants using APV as their most common order also increased in both conditions (Fig. 4, bottom row; see also Table 3). Interestingly, all of the participants who predominantly used APV in block 1 continued to use this as their most common order in block 2. This suggests that responses

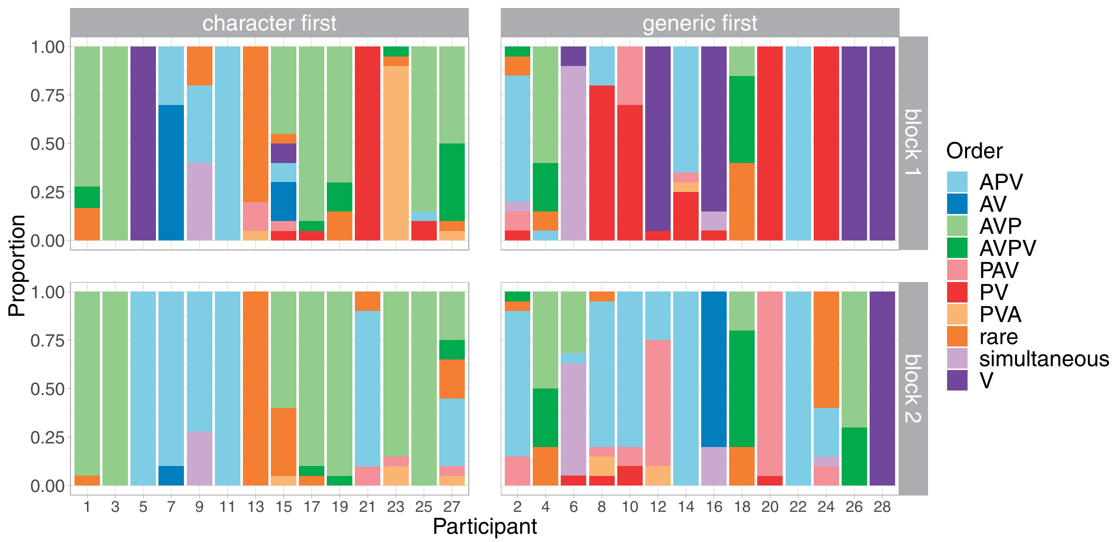

Figure 4 The proportion of orders used by each participant grouped by condition and block. A minority of participants used predominantly APV in block 1. Participants showed a strong tendency to omit noun referents, particularly agents, in block 1 of the generic-first condition. These results also demonstrate a tendency for individuals to perseverate block 1 ordering preferences into block 2.

Table 3 Number of participants in each condition and block who produced predominantly APV, AVP, or incomplete orders.

Word order	Character-first		Generic-first	
	Block 1	Block 2	Block 1	Block 2
APV	2	**6**	**3**	5
AVP	7	**7**	**1**	2
Incomplete	3	**0**	**8**	2

Cells in normal font indicate character-agent trials; cells in boldface show generic-agent trials.

in the second block were influenced by the pattern established in the first.

The use of AVP across blocks provides further evidence for this self-priming effect. As in block 1, participants in the character-first condition continued to use predominantly AVP in block 2. Consequently, this was the preferred order for describing character-agent events in block 1 (36.3%) and generic-agent events in block 2 (48.3%). Participants in the generic-first condition continued to use AVP in a minority of trials (12.2%). Of the eight participants who predominantly produced AVP in block 1, all but one (participant #27 in the character-first condition; see Fig. 4) continued this pattern into block 2.

As in the first block, participants in block 2 typically expressed the agent before the patient (80.4% of 235 character-agent trials; 92.7% of 259 generic-agent trials; see Fig. 7). Again, a mixed-effects logistic regression analysis confirmed that there was no significant difference between agent types (Table 8).

The tendency to omit constituents was considerably lower in block 2 compared with the first block. Figure 8 shows the proportion of trials for each agent type in which the agent (left) or patient (right) was omitted. Interestingly, the two participants who produced predominantly incomplete orders in block 2 had also done so in block 1 (see Fig. 4). This observation provides further evidence that participants tended to perseverate the pattern of responses established in block 1 into block 2.

An analysis of omissions across blocks confirmed that participants were significantly less likely to omit agents in block 2 compared with block 1 (Table 9). This may reflect a novelty effect: participants who had not attended to agents in the first block, or who had not considered them sufficiently worthy of mention, may have been more likely to attend to and mention agents in block 2 because they differed from those in block 1. We also found a significant interaction between block and agent type, reflecting the fact that the rate of generic-agent omissions dropped markedly from blocks 1 to 2, whereas character-agent omissions were already infrequent in both blocks.

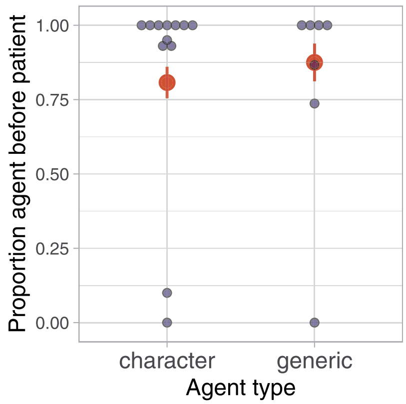

Figure 5 The proportion of block 1 trials in which the agent was expressed before the patient. Small circles represent the proportion of agent-before-patient responses for each participant. Large circles represent the overall means for each agent type (error bars show 95% CIs). For both agent types, participants expressed the agent before the patient in a majority of trials.

As in block 1, a comparison of patient omissions across blocks revealed a significant interaction between agent type and image orientation (Table 10). There were no other significant effects or interactions.

2.5.3.1 Block 2 discussion. The analysis of block 2 word orders revealed evidence of a self-priming effect whereby participants tended to continue using the same overall pattern of responses that they had used in block 1. The second key result was that the tendency found in block 1 to omit generic agents was not seen in the second block.

2.6 APV responses: a comparison with previous studies

In this section, we turn our focus to the unexpectedly low occurrence of APV in our data and compare our findings with two previous silent gesture studies, namely Goldin-Meadow et al. (2008) and Gibson et al. (2013).

Goldin-Meadow et al. (2008) found that APV (glossed as ArPA) was the preferred order for describing transitive events based on an analysis of gesture strings categorized as consistent with this order. Crucially, this category included the incomplete orders AV and PV.[6] Coding our own results according to this approach,[7] we found that orders consistent with APV in block 1

Table 4 Mixed-effects logistic regression analysis of agent-before-patient responses in block 1.

Predictor[a]	*B*	*SE*	*p*-value
Intercept	8.276	2.593	0.001**
agent_type	–0.503	2.993	0.866
orientation[b]	–0.707	2.785	0.800
agent_type: orientation	–0.736	1.991	0.712

Model: a_before_p ~ agent_type*orientation + (1 + orientation—participant) + (1—item).

[a]Binary inputs were deviation coded in all models in this study. The reported random effects structures represent the maximal structures for which models converged without warnings.

[b]Orientation was a binary flag indicating if the agent appeared on the left (coded –0.5) or the right (coded 0.5) of the image.

** $p \leq 0.01$.

accounted for a majority of generic-agent trials (63.9%) and just under one-third of character-agent trials (30.9%). In block 2, 36.0% of generic-agent trials were consistent with APV, and 45.6% of character-agent trials. These results are plotted in Fig. 9a.

Our results coded according to an alternative strategy used by Gibson et al. (2013) are plotted in Fig. 9b. Under this coding scheme, all trials in which the patient was expressed before the action were coded as APV-like (glossed as SOV). The authors reported that this was the majority order produced by English-speaking participants. However, closer inspection of their data (reported in Futrell et al. 2015) shows that APV accounted for only 31.6% of analysed trials,[8] followed closely by AVP (28.7%). The proportion of responses coded as PV, and included in the APV-like category, was 23.6%. In our own data, block 1 responses in which the patient was expressed before the action comprised the majority of generic-agent trials (88.6%)[9] and a large proportion of

6 Goldin-Meadow et al. (2008) reported that participants produced 501 gesture strings containing two elements, compared with only 113 complete strings.

7 To be consistent with the results reported in Goldin-Meadow et al. (2008) we calculated all percentages based on the set of trials containing at least one occurrence of the agent or patient. Trials in which only the action was expressed were therefore not included.

8 These percentages are based on data collected from English-speaking participants and include trials involving an animate agent and inanimate patient. Futrell et al. (2015) do not report trials in which the patient was not expressed, or where the patient and/or action were expressed more than once.

9 Consistent with Gibson et al. (2013), the figures reported in this section exclude trials in which the patient was not expressed, or the where the patient and/or action were expressed more than once.

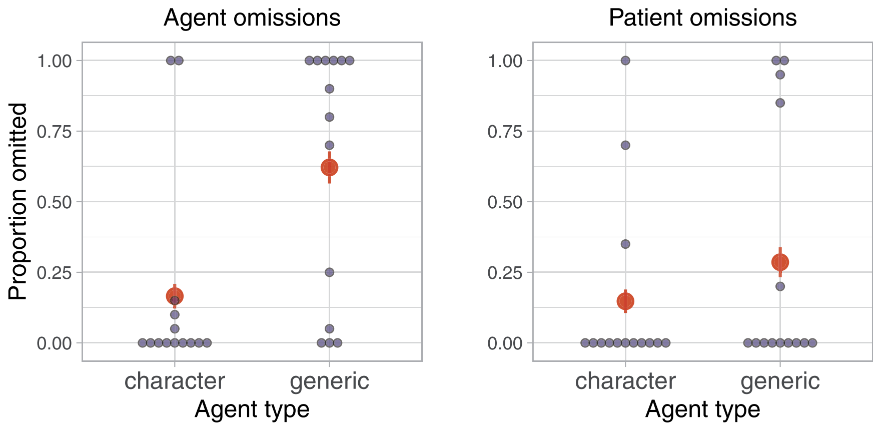

Figure 6 The proportion of agent and patient omissions in block 1. Blue circles indicate proportions for each participant. Large circles show the means for each agent type (error bars show 95% CIs). Participants were significantly more likely to omit generic agents compared with character agents.

Table 5 Mixed-effects logistic regression analysis of agent omissions in block 1.

Predictor	β	*SE*	*p*-value
Intercept	–0.727	1.400	0.604
agent_type	20.714	6.470	0.001**
orientation	1.025	0.969	0.290
agent_type: orientation	0.200	1.477	0.892

Model: a_omitted ~ agent_type*orientation + (1—participant) + (1—item).
** $p \leq 0.01$.

Table 6 Mixed-effects logistic regression analysis of patient omissions in block 1.

Predictor	β	*SE*	*p*-value
Intercept	–11.953	2.128	<0.001***
agent_type	1.183	3.173	0.709
orientation	0.463	0.588	0.431
agent_type: orientation	–3.481	1.180	0.003**

Model: p_omitted ~ agent_type*orientation + (1—participant).
** $p \leq 0.01$.
*** $p \leq 0.001$.

character-agent trials (46.1%). In block 2, we found the reverse pattern: patient-before-action response accounted for a majority of character-agent trials (78.8%) and a substantial proportion of generic-agent trials (42.3%).

These analyses show that our results are more closely in line with findings from previous studies than our original analysis suggests. In particular, for generic-agent trials in block 1, orders classified as consistent with APV

Table 7 Mixed-effects logistic regression analysis of APV responses across blocks.

Predictor	*B*	*SE*	*p*-value
Intercept	–5.215	2.415	0.031*
agent_type	–0.519	1.261	0.681
block	1.436	3.088	0.642
orientation	0.052	0.751	0.945
agent_type: block	–2.234	5.478	0.683
agent_type: orientation	0.211	0.588	0.720
block: orientation	–0.103	0.725	0.888
agent_type: block: orientation	–0.694	1.396	0.619

Model: is_apv ~ agent_type*block*orientation + (1 + block + orientation—participant).
* $p \leq 0.05$.

in other studies comprised the majority of trials. However, it is not clear that we should therefore interpret our findings as providing evidence for an APV bias for this type of event. The coding strategy adopted by Gibson et al. (2013), which equates all patient-before-action orders with APV, is not well motivated. In particular, it leads to the odd conclusion that both PAV and PVA, in addition to PV, are APV-like.

What about categorizing AV and PV as consistent with APV, as in Goldin-Meadow et al. (2008)? This approach is based on the assumption that incomplete orders represent surface manifestations of underlying predicate frames from which constituents have been dropped (Goldin-Meadow 1985; Goldin-Meadow et al. 2009). For transitive events, these frames consist of an APV. Furthermore, the strategy assumes that AV and PV derive from an underlying APV sequence where either

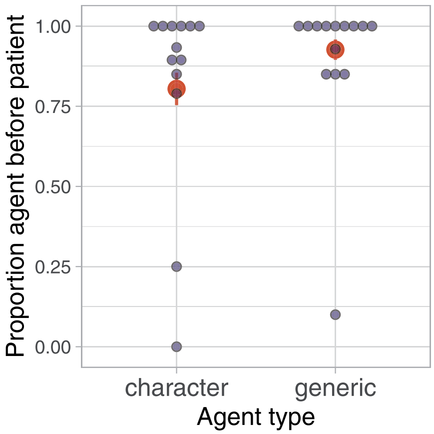

Figure 7 The proportion of block 2 trials in which the agent was expressed before the patient. Small circles represent the proportion of agent-before-patient responses for each participant. Large circles represent the overall means for each agent type (error bars show 95% CIs). For both agent types, participants expressed the agent before the patient in a majority of trials.

the agent has been dropped from initial position (resulting in PV), or the patient from second position (resulting in AV). In other words, it assumes *a priori* that the agent would have preceded the patient had both constituents been expressed. Again, it is unclear whether this assumption is warranted. For this reason, in Section 3, we present details of an alternative, computational method for dealing with missing constituents that does not require these *a priori* assumptions to be made.

2.7 Discussion

Based on findings from previous silent gesture studies, we predicted that participants would predominantly describe events using APV. We further predicted that participants would express generic agents before patients less often than character agents, resulting in fewer APV responses and correspondingly more PAV. Our results were not consistent with either prediction. Overall, we found that APV constituted around one quarter of responses, roughly equal to the proportion of responses coded as AVP. In addition, we found no evidence that the tendency to express the agent before the patient was conditioned on agent type.

Nevertheless, our results did provide evidence that participants were sensitive to the properties of the event agent. In block 1, AVP was the most common order for describing character-agent events. For generic-agent events, on the other hand, AVP was rare and participants showed a strong tendency to omit constituents, particularly the agent. Another key finding was that

Table 8 Mixed-effects logistic regression analysis of agent-before-patient responses in block 2.

Predictor	β	*SE*	*p*-value
Intercept	4.719	1.416	<0.001***
agent_type	1.894	1.793	0.291
orientation	–0.707	0.447	0.113
agent_type: orientation	1.044	0.888	0.240

Model: a_before_p ~ agent_type*orientation + (1—participant) + (1—item).
*** $p \leq 0.001$.

results from block 2 pointed to the presence of a self-priming effect whereby the preferred word orders established in block 1 perseverated into block 2.

Finally, in this section, we presented a reanalysis of our data where we found that our results were more aligned with previous findings, particularly for generic-agent events in block 1, if we recoded our data according to the strategies employed in two previous silent gesture studies. Nevertheless, these strategies are problematic: equating *all* patient-before-action responses with APV (Gibson et al. 2013) does not seem well motivated, while equating AV and PV with APV (Goldin-Meadow et al. 2008; Hall et al. 2013) relies on *a priori* assumptions about the relative positioning of dropped constituents.

We propose an alternative to this latter approach, making the weaker assumption that incomplete orders may in principle derive from *any* consistently ordered complete sequence, that is, sequences exhibiting the same relative ordering of expressed constituents. For example, PV may derive from dropping the agent from an underlying APV, PAV, or PVA sequence. In the next section, we describe details of a computational model that exploits this assumption to infer the distribution of complete orders that participants would have produced had they expressed all three constituents on every trial. The model also provides an estimate of the distribution of complete orders from which each incomplete order derived, for example, the proportions of PV responses that derived from APV, PAV, and PVA.

3. Modelling the underlying word order distribution

The results of this study demonstrate that improvised, gestured descriptions of events can be messy. That is, rather than consistently producing three-element sequences from which the constituent order can be unambiguously determined, participants often repeat elements or omit them altogether. Although some

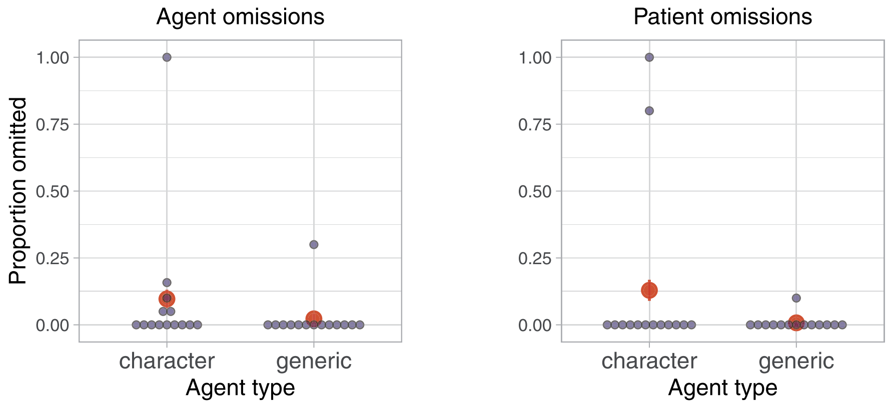

Figure 8 The proportion of agent and patient omissions for each agent type in block 2. Blue circles indicate the proportions for each participant. The large circles show the means for each agent type (error bars represent 95% CIs).

Table 9 Mixed-effects logistic regression analysis of agent omissions across blocks.

Predictor	*B*	*SE*	*p*-value
Intercept	–5.794	1.792	0.001**
agent_type	6.181	4.036	0.126
block	–8.250	3.223	0.011*
orientation	0.582	0.476	0.222
agent_type: orientation	1.139	0.953	0.232
agent_type: block	–20.684	7.305	0.005**
block: orientation	–0.416	0.928	0.654
agent_type: block: orientation	2.178	1.869	0.244

Model: a_omitted ~ agent_type*block*orientation + (1 + block—participant) + (1—item).
* $p \leq 0.05$.
** $p \leq 0.01$.

Table 10 Mixed-effects logistic regression analysis of patient omissions across blocks.

Predictor	β	*SE*	*p*-value
Intercept	–15.560	5.740	0.007**
agent_type	–0.254	2.849	0.929
block	–6.679	11.650	0.567
orientation	0.490	0.554	0.376
agent_type: orientation	–2.163	0.950	0.023*
agent_type: block	–2.837	7.578	0.708
block: orientation	0.000	1.05	1.000

Model: p_omitted ~ agent_type*block*orientation + (1 + block—participant).
* $p \leq 0.05$.
** $p \leq 0.01$.

studies in the silent gesture literature excluded incomplete orders from their analysis (e.g., Schouwstra and de Swart 2014), this approach was not appropriate in this study, for two reasons. First, the proportion of incomplete orders was relatively high, which may tell us something important about how people responded to the set of stimuli. Secondly, and more importantly, we saw in Section 2.5.2 that the tendency to omit event constituents, particularly the agent, was greater in block 1 when participants described generic-agent events compared with character-agent events. Excluding incomplete orders would obscure this conditioning on agent type.

As discussed in Section 2.6, Goldin-Meadow et al. (2008) attempted to deal with incomplete orders by binning them with one of the three-element orders. However, this approach is problematic since it makes *a priori* assumptions about the relative positioning of dropped constituents. In seeking to address the question of what factors influence the relative ordering of the three basic constituents, how else might we deal with situations where the rate of omissions is high? One obvious response to this question is that we should endeavour to encourage participants to express all three constituents. The passive exposure phase used in this study was not successful in achieving this. As we noted in Section 2.3, alternative approaches taken in the silent gesture literature have been similarly unsuccessful and/or may not be appropriate under all circumstances.

In this section, we present details of a computational method for dealing with missing constituents that not only avoids these methodological problems, but, more importantly, does not require *a priori* assumptions about the

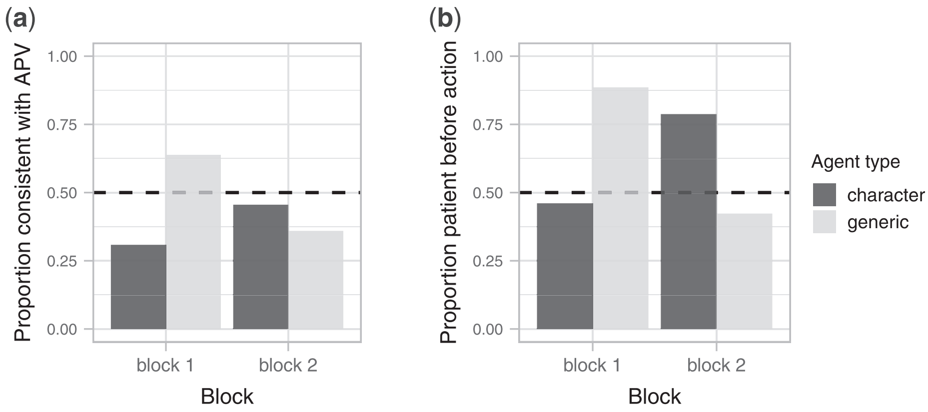

Figure 9 The proportion of responses coded as (a) consistent with APV, following Goldin-Meadow et al. (2008) and (b) patient-before-action, following Gibson et al. (2013). A majority of generic-agent trials in block 1 were categorized as APV-like, according to the coding strategies adopted in these two studies.

positioning of omitted constituents. The model described here infers an *underlying distribution* across the six basic word orders (APV, AVP, PAV, PVA, VAP, and VPA) based on the empirically derived distribution across the set of eleven complete and incomplete orders (APV, AVP, PAV, PVA, VAP, VPA, AV, PV, VA, VP, and V)[10] based on the assumption that incomplete sequences may derive from any consistently ordered complete sequence.

Details of the model are provided below. In brief, it proceeds by sampling candidate underlying distributions from the space of possible distributions. Each candidate distribution is transformed into a *surface distribution* using the probabilities of omitting the agent, patient, or both. The inferred underlying distribution corresponds to the surface distribution that best fits the empirically derived data. For each incomplete order, the model also provides an estimate of the proportion that derives from each complete order.

3.1 Generating the surface distribution

For a given word order in a candidate underlying distribution, the model generates a sub-distribution consisting of the proportion of the original order and the proportions of each transformed order. For example, if the original order is APV, the resulting sub-distribution represents the proportions of APV, AV, PV, and V sequences. The proportion of each transformed order is calculated using the set of omission probabilities, that is, the probabilities that the agent, patient, or both are omitted. More formally, the proportion of each transformed order t_{-c} is given by

$$P(t_{-c}) = P(w) \times O(c),$$

where t_{-c} represents a transformed order that excludes constituent(s) c, $P(w)$ is the proportion of the original word order w within the candidate underlying distribution, and $O(c)$ is the omission probability for constituent(s) c. Following the transformation procedure, the remaining proportion $P_{\text{remaining}}(w)$ of the original order is calculated by subtracting each $P(t_{-c})$ from $P(w)$ such that $P(w) = P_{\text{remaining}}(w) + \sum_{c \in C} P(t_{-c})$, where C is the set of constituent(s) that can be omitted (i.e., agent, patient, and both).

As an example, suppose the proportion of APV sequences in the candidate distribution is $P(\text{APV}) = 0.5$. Suppose further that the probability of an agent omission $O(\text{A}) = 0.2$, the probability of a patient omission $O(\text{P}) = 0.1$, and the probability that both are omitted $O(\text{A} + \text{P}) = 0.1$. This means that 20% of APV responses are transformed to PV, 10% are transformed to AV, and 10% are transformed to V. The resulting sub-distribution across APV, AV, PV, and V then contains $P_{\text{remaining}}(\text{APV}) = 0.3$, $P(\text{AV}) = 0.05$, $P(\text{PV}) = 0.1$, and $P(\text{V}) = 0.05$, which sum to 0.5. This procedure is repeated for each of the six basic word orders and the resulting sub-distributions combined to give a transformed surface probability distribution across the eleven complete and incomplete orders. The model also records the proportion of each incomplete order within the surface distribution that derived from each complete order, for example, the proportions of PV that derived from APV, PAV, and PVA.

10 Participants in our study expressed the action on every trial, hence, all incomplete orders include this constituent.

3.2 Inferring the underlying distribution

We used a least-squares method to determine the surface distribution that best fits the observed data. The model employed a basin-hopping global optimization algorithm in the Python SciPy optimize package.[11] The procedure repeatedly sampled candidate distributions across the six basic orders that were then transformed to a candidate surface distribution according to the procedure described above. The objective function (i.e., the function whose output was to be minimized) represented the squared residuals between the observed distribution and the candidate surface distribution. The inferred underlying distribution corresponded to the candidate surface distribution that minimized the objective function. Below, we present results from two model parameterizations. In one, the model inferred the underlying distribution and received the set of omission probabilities $O(A)$, $O(P)$, $O(A+P)$ as fixed parameters. The probabilities were determined empirically, one set for each agent type. In the other model, the omission probabilities were free parameters estimated by the model.

3.3 Results

For this analysis, we focused on block 1 responses since the rate of omissions in the second block was very low. The values specifying the initial estimate of the underlying distribution (used as a starting point by the model) were $P(\mathrm{APV}) = P(\mathrm{AVP}) = P(\mathrm{PAV}) = P(\mathrm{PVA}) = 0.2$, and $P(\mathrm{VAP}) = P(\mathrm{VPA}) = 0.1$. Where the omission probabilities were estimated by the model, initial values were $\mathrm{O(A)} = \mathrm{O(P)} = \mathrm{O(A+P)} = 0.2$.

Table 11 shows the results of the model for generic agent and character agent events. We calculated the Akaike information criterion (AIC) to compare the two model parameterizations. AIC estimates the goodness of fit of a model and adjusts for the number of estimated parameters to reduce the risk of overfitting (Gelman and Hill 2006: 524–525). For generic-agent events, the free omission probabilities model provided a better fit to the data. For character-agent events, the fixed omission probabilities model resulted in a better fit.

Figure 10a shows bootstrap mean proportions for each word order in the observed and best-fit surface distributions for generic-agent events. These data were generated by drawing 10,000 samples of $n = 232$ trials, where the probability of drawing a particular word order was given by the empirically derived proportion in the observed distribution and estimated proportion in the best-fit surface distribution, respectively (see Appendix C.1). The sample size n corresponded to the number of trials in the observed data. The plot also shows data simulated from the inferred underlying distribution ($n = 76$). Simulation results for character-agent events are plotted in Fig. 10b (surface distribution: $n = 227$; underlying distribution: $n = 163$). The data are provided in Appendix C.2. For both types of event, the proportion of each word order in the best-fit surface distribution closely matches the observed distribution, with some exceptions that we return to below.

Consistent with our analysis of block 1 responses, the model indicated that AVP was the preferred order for character-agent events (estimated mean = 0.584, 95% CI 0.509–0.656), but was much less common for generic-agent events (estimated mean = 0.087, 95% CI 0.026–0.158). The model also suggested a strong APV preference for generic-agent events (estimated mean = 0.746, 95% CI 0.645–0.842), but not for character-agent events (estimated mean = 0.234, 95% CI 0.172–0.301).

Table 12 shows the proportion of each incomplete order that derived from each of the six complete orders. For generic-agent events, the model estimated that a majority of AV (0.766) and PV (0.817) derived from an underlying APV order. This finding may suggest that assuming *a priori* that AV and PV originate as APV, as in Goldin-Meadow et al. (2008), is a sound approach. However, model estimates based on data from character-agent events show that this assumption does not hold in general. Here, just over half of PV (0.570) derived from APV, while around one-third originated as PVA (0.323); fewer than one-third of AV (0.271) responses came from APV, while the majority (0.678) derived from AVP.

In fact, these findings are not surprising and are a direct consequence of the fact that the model described here transforms all orders according to the same set of omission probabilities. Thus, PV responses, for example, will be distributed across APV, PAV, and PVA according to the relative frequency of these orders in the underlying distribution. To make this more explicit, if the underlying distribution contains equal proportions of these three orders, then the transformed PV responses will be distributed evenly across them.

We now return to the divergences between the best-fit surface distributions and the observed distributions. For generic-agent events, the model underestimated the proportion of AVP responses (observed: mean = 0.065, 95% CI 0.034–0.099; model estimate: mean = 0.026, 95% CI 0.009–0.047) and overestimated the proportion of VP (observed: zero occurrences; model estimate: mean = 0.032, 95% CI 0.013–0.056). For character-

11 SciPy package version 1.4.1.

Table 11 Model output for each agent type using two model parameterizations.

Agent type	Omission probabilities	Objective function	AIC	O(**A**)	O(**P**)	O(**A** + **P**)
Generic	Fixed	0.0077	70.23	0.3429	0.0071	0.2786
	Free	0.0025	64.12	0.3645	∼0	0.3361
Character	Fixed	0.0091	95.59	0.0863	0.0683	0.0791
	Free	0.0081	155.43	0.0814	0.0893	0.0970

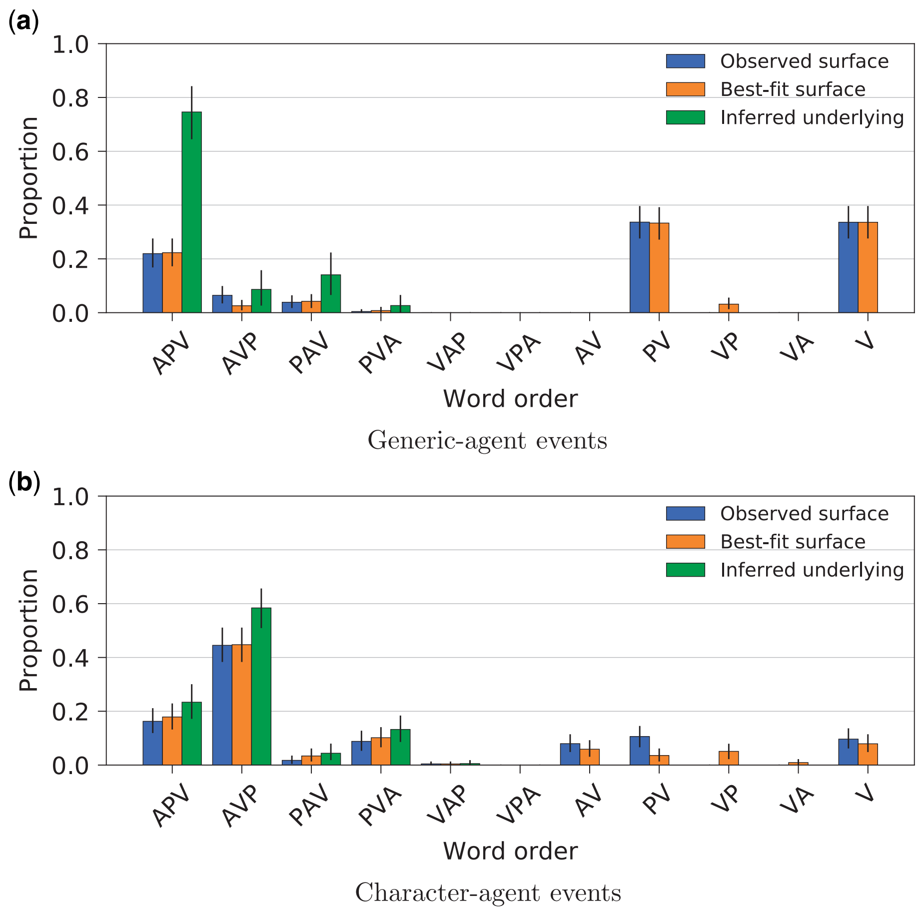

Figure 10 Bootstrap mean proportions of each word order in the observed distribution across surface orders, the best-fit surface distribution, and the inferred underlying distribution for (a) generic-agent events and (b) character-agent events. Error bars represent 95% confidence intervals.

agent events, the model underestimated PV (observed: mean = 0.106, 95% CI 0.066–0.145; model estimate: mean = 0.036, 95% CI 0.013–0.062) and again overestimated VP (observed: zero occurrences; model estimate: mean = 0.051, 95% CI 0.022–0.079). These findings indicate that the model may not fully capture the mechanism by which surface orders are generated. It is notable, for example, that while AV and PV are frequently attested in studies of homesign systems (Goldin-Meadow et al. 2009) and emerging sign languages (e.g. Sandler et al. 2005; Padden et al. 2010), action-initial constructions are much rarer. One possibility is that the

Table 12 Proportion of each incomplete order that derived from each complete order.

		APV	AVP	PAV	PVA	VAP	VPA
	AV	0.766	0.089	0.145	0	0	0
	PV	0.817	0	0.156	0.029	0	0
	V	0.746	0.087	0.141	0.026	0	0
	VA	0	0	0	1.0	0	0
Generic[a]	VP	0	1.0	0	0	0	0
	AV	0.271	0.678	0.051	0	0	0
	PV	0.570	0	0.107	0.323	0	0
	V	0.234	0.584	0.044	0.133	0.006	0
	VA	0	0	0	0.960	0.040	0
Character[b]	VP	0	0.991	0	0	0.009	0

[a]Omission probabilities free parameters of the model.
[b]Omission probabilities fixed parameters of the model.

probability of dropping a constituent may vary between word orders. For example, there may be a smaller probability of dropping the agent from an underlying AVP sequence compared with APV.[12]

3.4 Discussion

We developed a computational model that infers an underlying distribution across the six basic word orders by assuming that incomplete orders derive from complete orders where one or more noun referents have been dropped. The set of probabilities of dropping the agent, patient, or both was either provided to the model as fixed parameters or was estimated by the model. The model also provided an estimate of the proportions of each incomplete order that derived from each complete order.

We used this model to infer the word orders that participants in block 1 would have produced had they expressed all three constituents on every trial. Consistent with the analysis of the empirically derived word order distributions, the model showed that AVP was the preferred order for describing character-agent events. Our model also indicated that for generic-agent events, the majority of incomplete orders derived from APV, resulting in an overall preference for this order in the inferred underlying distribution. However, we also saw that one cannot make *a priori* assumptions about the source of incomplete orders. In particular, under the assumptions of the model described here, it is not generally the case that AV and PV derive from an underlying APV order.

12 Another possibility is that a two-gesture sequences may be further transformed, for example, from VP to PV, to avoid expressing the action in initial position. We explored this possibility by allowing the model to estimate the probability of reversing the order of V-initial incomplete sequences. This model performed exceptionally well, producing estimated surface distributions that exactly matched the observed distributions. However, this approach was *post hoc* with little theoretical or empirical backing; hence, we do not discuss the details here.

4. General discussion

Goldin-Meadow et al. (2008) proposed that APV (usually glossed as SOV in the silent gesture literature) is cognitively more basic than other word orders and is the default order adopted by all emerging communication systems. However, a growing body of literature has challenged this conclusion. Meir et al. (2017), for example, have argued that APV is no more cognitively basic than other orders, but reflects the relative salience of interacting entities: humans, which are typically agents, are more salient than inanimate objects and so tend to be mentioned first.

We had two main aims in the this study. First, we sought to replicate the APV bias in a silent gesture task. Secondly, we set out to explore the role of salience in more detail. Specifically, we attempted to manipulate the salience of the agent in an event to investigate the hypothesis that the tendency to express the agent before the patient would be reduced for less salient agents, resulting in correspondingly more PAV responses.

Contrary to our first expectation, participants did not produce predominantly APV. In addition, we found no evidence that agent type influenced the relative ordering of the agent and patient. Nevertheless, we did find clear evidence of word order conditioning on agent type. In block 1, participants typically described character-agent events using AVP. However, this order was rare for generic-agent events. In addition, we found that participants in block 1 showed a strong tendency to omit generic agents from their descriptions. Of the orders in which at least one noun referent was expressed, PV occurred most frequently for this type of event. Responses in block 2 pointed to a strong self-priming effect whereby participants continued to produce the same ordering preferences they had established in block 1.

Previous literature has made it obvious that in eliciting spontaneous, improvised utterances, it is hard to make participants include all information. As we discussed in Section 2.3, while adding a communicative component may have encouraged participants to be more informative, this approach was not appropriate for this study. Moreover, previous studies suggest that improvization may play out differently in a fully communicative setting (Hall et al. 2015; Schouwstra et al. 2020, preprint). In Section 3, we presented details of a computational model that avoided these methodological issues and inferred the word orders participants would have produced had they expressed all three constituents on every trial. This model provides an innovative way to deal with incomplete datasets, which we expect to be of potential use for others in the field. The model exploited the assumption that incomplete orders derive from an underlying complete order where one or more constituents have been omitted. The results of this analysis suggested that APV was the preferred order for describing generic-agent events in block 1, modulated by a strong tendency to omit the agent. In contrast, and consistent with our analysis of the observed data, AVP was the most common order for character-agent events.

4.1 Salience and word order

4.1.1 Generic-agent omissions

We saw in Section 2.5.2 that the rate of agent omissions in block 1 was significantly higher for generic agents than for character agents. We suggested that this reflected the relative salience of the two types of agent. But why should less salient entities be omitted rather than expressed later in the sequence, as we predicted based on the salience hypothesis proposed by Meir et al. (2017)? One possible explanation relates to the embodied nature of gestured descriptions. We observed that people typically enacted event actions, for example, miming the act of pushing using their own hands. In so doing, they in effect embodied the role of the agent while expressing the action. This phenomenon has been described in previous silent gesture studies (e.g., Hall et al. 2013; Kocab et al. 2018), and its presence is unsurprising given the performative nature of silent gesture.

One conclusion we can draw from this observation is that agents were not completely omitted from descriptions; rather, what was omitted was explicit reference to their physical attributes. More precisely, while some properties of the agent were encoded in the form of the action[13] (it is human, it acts volitionally, etc.), other properties such as gender or items of clothing were not expressed, presumably because they were not considered relevant in the context of the task. Such omissions were less likely to occur for character agents in block 1, we argue, because their physical characteristics were more salient and therefore more worthy of mention. It is also worth noting that in block 2, we saw a reduction in agent omissions across the board. We suggested that this may reflect a novelty effect: switching the set of agents may have made their individual attributes more salient and therefore more likely to be mentioned explicitly.

An alternative explanation for the tendency to omit generic agents in block 1 is that these were less easy to describe iconically than were character agents.[14] While this may form part of the explanation, the fact that the rate of generic-agent omissions was negligible in block 2 suggests that this cannot be the full story. In addition, as we noted in the Introduction, agent omission is widespread in sign languages and, consistent with our own interpretation, has been analysed as an agent backgrounding device (e.g., Kegl 1990; Janzen et al. 2001; Barberà et al. 2018; Rissman et al. 2020).

4.1.2 AVP and (A)PV

An unexpected finding in block 1 was that agent type influenced the relative order of the patient and action: AVP was common for character-agent events, and (A)PV for generic-agent events. Here, we argue that the

13 A similar phenomenon has been described in sign languages. In so-called body-anchored verbs, the body is associated with the subject argument, and the form of the sign encodes some property of the subject, for example, that it has a mouth (Meir et al. 2007). Hall et al. (2013) discuss the relationship between body-as-agent in improvised gesture and body-as-subject in sign language.

14 We thank an anonymous reviewer for this suggestion.

salience of the agent can influence constituent order indirectly by affecting the way participants construe events. This view on the role of salience differs from previous proposals (Meir et al. 2017), where salience is proposed as a direct influencer of constituent order.

We first consider the preference for expressing the action in final position when describing generic-agent events. While this pattern is consistent with previous proposals, for example, that concrete entities tend to be mentioned before abstract relations (Goldin-Meadow et al. 2008), an alternative explanation is that (A)PV, or PV more specifically, may reflect a patient-focused construal of an event. Where the identity of the agent is non-salient, the event may be more likely to be framed from the patient perspective. Consequently, the patient represents what Bock and Ferreira (2014) terms the 'aboutee' and forms the starting point of the utterance (MacWhinney 1977), while the agent is backgrounded through omission (Rissman et al. 2020).

The preference for describing character-agent events using AVP, on the other hand, is not only surprising in light of previous findings in the silent gesture literature, but also cannot be readily accommodated within any of the accounts discussed previously. Here, we offer a number of possible explanations. The first possibility is that AVP may have resulted from prolonged attentional focus on the agent. We observed that, in contrast to generic-agent descriptions, character-agent descriptions were often highly detailed.[15] In directing a large amount of attention to their physical attributes, participants may have more naturally proceeded to describing the action being performed by the character before turning their attention to the patient. If this explanation is correct, it raises important questions about the extent to which our findings reflect task-specific factors. For example, if participants were in some way restricted to providing the same amount of information about event agents, say, a single gesture, then this might potentially eliminate word order differences.

A related, task-agnostic explanation is that by analogy with the proposal that (A)PV reflects a patient-centred construal of an event, AVP may reflect an agent-centred construal. Accordingly, the agent is mentioned first, while the patient is expressed after the action reflecting its status as the background against which the agent performs the action. Thus, a highly agent-focused construal of an event could be glossed as 'There is some character. This is the action they perform. This is the thing the action is directed towards'.

A third, perhaps more parsimonious explanation, is that both AVP and PV reflect native-language influence. AVP can be equated with SVO, while PV is analogous to the English passive construction where the *by*-phrase is not expressed, for example, *the clock is pushed (over)*. This interpretation of the data similarly leads to an explanation based on salience and event construal. The relatively high salience of character agents promotes an active, agent-focused construal, while events involving less salient, generic agents result in a passive, patient-focused construal. We return to the question of native-language influence below.

The proposal that salience influences event construal is, to our knowledge, new in the silent gesture literature. However, it is by no means new to the study of language production. Vogels et al. (2013), for example, argued that salience influences the global interpretation of a scene, which in turn affects structural choices. Similarly, Antón-Méndez (2017) proposed that event descriptions focus on what the more visually salient entity is doing or experiencing. In another study, as previously discussed, Rissman et al. (2018) argued that manipulating the salience of the agent affected whether participants provided an agent- or patient-focused construal of an event.

4.2 Silent gesture, native language, and word order

In the accounts outlined above, we suggested that AVP may result from increasing the salience of an event agent. However, although agent salience is typically not controlled for in the silent gesture literature, it is certainly not the case that previous studies have consistently used stimuli depicting 'generic' humans (Schouwstra and de Swart 2014, for example, used events depicting witches, divers, and princesses, among others). Nevertheless, ours is the first study to find that events involving highly salient agents elicit AVP rather than APV. A possible source of this discrepancy might be the type of event used in this study. Events in silent gesture studies often involve handling or manipulation of the patient (e.g., Goldin-Meadow et al. 2008; Schouwstra and de Swart 2014; Christensen et al. 2016), for

15 We also observed that people would sometimes include details that were not represented in the stimuli. For example, one participant consistently gestured a parrot sitting on his shoulder when describing the pirate, even though this was not depicted in the stimuli. We also observed examples of people enacting a stereotypical action associated with certain characters. For example, pantomiming cooking when describing the chef.

example, a witch eating a banana.[16] While the preference for APV has been attributed to the semantic relations between entities (e.g., Goldin-Meadow et al. 2008; Schouwstra 2012) or structural iconicity (Christensen et al. 2016), an alternative interpretation lies in the observation that the form of the action gesture in handling events is likely to be influenced by the identity of the patient (e.g., a gesture that depicts eating a banana is likely to be different from one that depicts eating, say, a steak). Pertinent to this is a generalization noted by Napoli and Sutton-Spence (2014) in a review of forty-two sign languages that if an argument affects the phonological shape of a verb, it typically precedes the verb (Generalization Two). This may in part explain why APV was less common in this study where the form of the action was independent of the patient.

In the discussion above, we noted that word order preferences in block 1 may reflect influence from the participants' native language. Despite the appealing simplicity of this suggestion, it is at odds with findings from previous silent gesture studies that have found no, or minimal, native language interference (e.g., Goldin-Meadow et al. 2008; Langus and Nespor 2010; Futrell et al. 2015). However, these findings might also be explained by the tendency to use manipulation events. If APV is the natural order for representing such events, then, by extension, other orders may feel unnatural and may be avoided.

This argument notwithstanding, a native-language interpretation of our own data is not clear cut. We found, for example, that on moving from blocks 1 to 2, participants in the generic-first condition who had predominantly produced PV tended to shift to APV. However, if word order reflects native language, then we might expect a shift from a patient-focused, passive construal (PV), to an agent-focused, active construal, realized as AVP. A further complication, however, is that people tended to continue using the same ordering strategies established in block 1 when progressing to the second block. Thus, shifting from PV to APV may represent a tendency to perseverate the order of the patient relative to the action while expressing the previously unseen agent in initial position.

The discussion presented here highlights the need for more research into how different event types influence structural choices in silent gesture and improvised communication (see also Schouwstra and de Swart 2014; Christensen et al. 2016). In addition, more work is required to understand how these effects interact with influences from native language. Our findings also draw attention to an important methodological issue in the silent gesture literature, namely, how gesture sequences are analysed. Excluding incomplete orders, or categorizing them as consistent with an underlying complete order, could obscure important phenomena that might tell us something about the cognitive biases that shape structural choices during improvization. Related to this is how improvised descriptions of events are interpreted. There is usually an implicit assumption in the literature that these can be mapped to a simple active clause. However, there are usually, if not always, multiple ways of representing the same event, and it would be surprising if this were not reflected in improvised communication.

5. Conclusion

The findings of this study support the hypothesis that word order in emerging communication systems reflects the relative salience of entities interacting in an event (Meir et al. 2017). However, rather than affecting word order directly, our results suggest that salience influences the perspective from which a producer frames an event, which in turn influences structural choices. Previous studies have demonstrated that word order in improvised communication is conditioned on certain properties of an event (e.g., Schouwstra and de Swart 2014; Christensen et al. 2016; Hall et al. 2013; Gibson et al. 2013; Kocab et al. 2018), challenging the claim that APV (or SOV) is the default order. Our results add an additional layer to that argument: naturalness as it relates to constituent order is conditioned not only on the inherent properties of an event, but is mediated by the perspective of the producer and how they construe an event.

Data availability statement

All data underlying this article are available on the Open Science Framework at https://osf.io/j46kq/.

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16 We acknowledge that while some studies used only manipulation events, others used a mix of these and other types of event (e.g., Langus and Nespor 2010; Hall et al. 2013; Gibson et al. 2013). Without a detailed breakdown of responses by event type, we can only speculate as to what, if any, the effect on word order might have been.

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Appendix A. List of items

Table A.13 Set of humans (agents), inanimate objects (patients) and actions.

Item	Category
Girl	generic human
Boy	generic human
Teenager	generic human
Woman	generic human
Man	generic human
Chef	character human
King	character human
Pirate	character human
Punk	character human
Viking	character human
bird table	object
Clock	object
Drawers	object
Plant	object
Push	action
Kick	action
Elbow	action
Poke	action

Appendix B. Patient-before-action responses in block 1

This supplementary analysis considered the proportion of trials in which the patient was expressed before the action in block 1 of testing. The data included all trials in which it was possible to determine the order of the first-mentioned patient with respect to the first-mentioned action. There were 410 such trials, representing 229 descriptions of character-agent events and 181 generic-agent events. Participants were significantly more likely to express the patient before the action when describing generic-agent events.

Table B.14 Mixed-effects logistic regression analysis of patient-before-action responses in block 1.

Predictor	β	*SE*	*p*-value
Intercept	4.818	1.985	0.015*
agent_type	6.257	2.989	0.036*
orientation	0.284	0.671	0.672
agent_type: orientation	0.736	1.359	0.588

Model: p_before_act ~ agent_type*orientation + (1—participant) + (1—item).

Appendix C. Model supplementary data

C.1.Generic-agent events

Table C.15 Bootstrap means and 95% CIs for each word order in the observed surface distribution, best-fit surface distribution, and inferred underlying distribution based on block 1 descriptions of generic-agent events.

	Observed distribution			Best-fit surface distribution			Inferred underlying distribution		
	Lower 95% CI	Mean	Upper 95% CI	Lower 95% CI	Mean	Upper 95% CI	Lower 95% CI	Mean	Upper 95% CI
APV	0.168	0.220	0.276	0.172	0.223	0.276	0.645	0.746	0.842
AVP	0.034	0.065	0.099	0.008	0.026	0.047	0.026	0.087	0.158
PAV	0.017	0.039	0.065	0.017	0.042	0.069	0.066	0.141	0.224
PVA	0	0.004	0.013	0	0.008	0.022	0	0.027	0.066
VAP	0	0	0	0	0	0	0	0	0
VPA	0	0	0	0	0	0	0	0	0
AV	0	0	0	0	0	0	NA	NA	NA
PV	0.276	0.337	0.397	0.272	0.333	0.392	NA	NA	NA
VA	0	0	0	0	0	0	NA	NA	NA
VP	0	0	0	0.013	0.032	0.056	NA	NA	NA
V	0.276	0.336	0.397	0.276	0.336	0.397	NA	NA	NA

The best-fit model had omission probabilities as free parameters. Observed and best-fit surface distribution data were generated by drawing 10,000 samples of $n = 232$ trials from each distribution. The inferred underlying distribution data were generated by drawing 10,000 samples of $n = 76$ trials.

C.2. Character-agent events

Table C.16 Bootstrap means and 95% CIs for each word order in the observed surface distribution, best-fit surface distribution, and inferred underlying distribution based on block 1 descriptions of character-agent events.

	Observed distribution			Best-fit surface distribution			Inferred underlying distribution		
	Lower 95% CI	Mean	Upper 95% CI	Lower 95% CI	Mean	Upper 95% CI	Lower 95% CI	Mean	Upper 95% CI
APV	0.119	0.163	0.211	0.132	0.179	0.229	0.172	0.234	0.301
AVP	0.383	0.445	0.511	0.383	0.448	0.511	0.509	0.584	0.656
PAV	0.004	0.018	0.035	0.013	0.034	0.062	0.018	0.044	0.080
PVA	0.053	0.088	0.128	0.066	0.102	0.141	0.086	0.132	0.184
VAP	0	0.004	0.013	0	0.004	0.013	0	0.006	0.018
VPA	0	0	0	0	0	0	0	0	0
AV	0.048	0.080	0.115	0.031	0.059	0.093	NA	NA	NA
PV	0.066	0.106	0.145	0.013	0.036	0.062	NA	NA	NA
VA	0	0	0	0	0.009	0.022	NA	NA	NA
VP	0	0	0	0.022	0.051	0.079	NA	NA	NA
V	0.062	0.097	0.137	0.048	0.079	0.115	NA	NA	NA

The best-fit model had omission probabilities as fixed parameters. Observed and best-fit surface distribution data were generated by drawing 10,000 samples of $n = 227$ trials from each distribution. The inferred underlying distribution data were generated by drawing 10,000 samples of $n = 163$ trials.