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Cognitive constraints on constituent order: Evidence from elicited pantomime

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Abstract

To what extent does human cognition influence the structure of human language? Recent experiments using elicited pantomime suggest that the prevalence of Subject-Object-Verb (SOV) order across the world's languages may arise in part because SOV order is most compatible with how we conceptually represent transitive events (Goldin-Meadow, So, Özyürek, & Mylander, 2008). However, this raises the question as to why non-SOV orders exist. Two recent studies (Meir, Lifshitz, Ilkbasaran, & Padden, 2010; Gibson et al., 2013) suggest that SOV might be suboptimal for describing events in which both the agent and patient are plausible agents (e.g. a woman pushing a boy); we call these "reversible" events. We replicate these findings using elicited pantomime and offer a new interpretation. Meir et al.'s (2010) account is framed largely in terms of constraints on comprehension, while Gibson et al.'s (2013) account involves minimizing the risk of information loss or memory degradation. We offer an alternative hypothesis that is grounded in constraints on production. We consider the implications of these findings for the distribution of constituent order in the world's spoken languages and for the structure of emerging sign languages.

Keywords

Word order; SOV; Gesture; Pantomime; Sign language; Production

1. Introduction

In natural languages, words refer to entities (e.g., cats, girls), states (bliss), and actions (petting). But we use natural language to describe more than just disconnected entities, states, and actions; we also describe how these relate to one another. To do so, we string words together into sentences (e.g., "The girl blissfully pets the cat"), so as to convey which entities are doing which activities to which other entities, in which states, and so forth. Thus, an important property of natural languages is that we require devices that allow us to not only convey who, what, and whom, but also who *did* what to whom.

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One way that different languages convey such information is by mentioning these major constituents in a specific order. For example, in an English active sentence like "The boy pushed the box," the noun phrase before the verb is the subject of that verb and so denotes the entity that performed the action (sometimes called the *agent*), and the noun phrase after the verb is the object of the verb and so denotes the entity that had the action performed on it (sometimes called the *patient*). In fact, in most English sentences that have both a subject and an object, this particular ordering – subject-verb-object or *SVO* – is used, leading English to be termed an SVO language. Other languages use different orders of constituents than SVO. For example, in Turkish, sentences that have both a subject and object tend to order the subject first, followed by the object and then the verb, leading Turkish to be termed an SOV language. (It is important to note that this paper focuses mainly on the relative order of the semantic roles of agent, action, and patient, which can be dissociated from the syntactic roles of subject, verb, and object, as in passive sentences such as, "The box was pushed by the boy." However, for ease of exposition, we adopt the nomenclature of S, V, and O.)

Curiously, the distribution of constituent orders across language families is far from even. SOV is dominant, with SVO a close second, and VSO a distant third. The remaining orders (OSV, VOS, OVS) are extremely rare (Dryer, 2008; Greenberg, 1966; Hawkins, 1983; Tomlin, 1986). Furthermore, languages are known to change from SOV toward SVO, but the reverse change is much rarer (Gell-Mann & Ruhlen, 2011; Givón, 1979; Li, 1977). This suggests that in the past, SOV languages were once more dominant than they are now. Indeed, some research on the origins of language argues that human proto-language had SOV constituent order (Newmeyer, 2000). In short, SOV orders are not only predominant in the world's present languages; they may have been even more so in the past.

The predominance of SOV order is unlikely to be solely due to sociolinguistic factors, such as which language communities contacted, conquered, or emigrated from which. For instance, SOV has quickly emerged as the dominant order of a young sign language (Al-Sayyid Bedouin Sign Language) that initially evolved with minimal contact from other sign languages, and where the ambient spoken languages use SVO (Sandler, Meir, Padden, & Aronoff, 2005). This is especially noteworthy given the observation that similar convergence at the phonological level has not yet occurred in this language (Aronoff, Meir, Padden, & Sandler, 2008). SOV and the related orders SV and OV have also been reported in the first generation of signers of another young sign language evolving in Nicaragua, although OSV was also observed (Senghas, Coppola, Newport, & Supalla, 1997). Haviland (2011) also reports preliminary evidence of SV, OV, and SOV emerging in an even younger sign system currently evolving in Mexico. This latter case is particularly interesting in that the ambient spoken language (Tzotzil) is robustly VOS. In all of these cases, the emergence of (S)OV cannot easily be attributed to any parent language, spoken or signed, and so is unlikely to be directly due to language contact.

Likewise, evidence suggests that persistent SOV preferences cannot be only due to learning biases during acquisition, or alignment among interlocutors. This is shown by cases where individuals create linguistic systems in the absence of input. Children are typically born into language-rich environments. However, children who are profoundly deaf from birth are sometimes not exposed to language until sometime after birth. While many of these children eventually receive linguistic input (either sign language or spoken language via hearing technology), others sometimes lack language input throughout childhood (Mayberry, Lock, & Kazmi, 2002). In these latter cases, children typically create a manual communication system known as homesign (Goldin-Meadow & Feldman, 1977). Parental contributions to these systems are minimal (Goldin-Meadow & Mylander, 1983); thus, whatever structure they exhibit can be attributed to a large extent to the child's own innovation. Research has shown that the constituent order of homesign systems is remarkably consistent. Rather than being a grab bag of all possible orders, individuals' utterances are mainly composed of a limited subset of these orders: SV and OV, which are both consistent with SOV, and familiar from the descriptions of emerging sign languages reviewed above (for a review, see Goldin-Meadow, 2003). This tendency is robust cross-culturally, suggesting that individual homesigners the world over have consistent preferences for constituent order (Goldin-Meadow & Mylander, 1998; Goldin-Meadow, Özyürek, Sancar, & Mylander, 2008). These observations point toward a cognitive preference for SOV in the absence of language input.

More relevant to the experiments reported here is the finding that a preference for SOV orders is not unique to deaf children. Goldin-Meadow So, et al. (2008) asked hearing non-signers from diverse linguistic backgrounds to describe transitive and intransitive events in pantomime. They found that for transitive events, participants showed a strong tendency to produce SV, OV, and SOV descriptions. This tendency was equally robust among SVO speakers (English, Spanish, Chinese) and SOV speakers (Turkish). These findings have since been replicated by Langus and Nespor (2010) as well as Gibson et al. (2013).

In sum, evidence from typology, new sign languages, homesign systems, and pantomime suggests that the SOV order may have a 'special' status. The final observation – that adults spontaneously and systematically pantomime events with SOV orders – points to a possible reason for this special status: SOV may be more compatible with the way that human cognitive systems tend to organize event knowledge. That is, people may think about dynamic events in such a way that they are more efficiently linearized in an SOV order (Goldin-Meadow So, et al., 2008). If so, SOV ordering would spontaneously emerge in humans' initial languages (both when language first emerged and today), which explains the appearance of SOV in homesign systems and in adults' spontaneous pantomime behavior.

However, despite the above evidence favoring SOV, there are also systematic ways in which languages shift away from SOV. Chief among these are two phenomena related to language change: rapid convergence on SVO when a pidgin becomes a creole, and gradual but unidirectional drift away from SOV. We briefly review each situation in turn.

The term *pidgin* refers to contact language that results when speakers of different languages are forced to communicate. Pidgins generally retain only the bare bones of linguistic structure from the input languages (i.e. the various native languages represented in the community). Thus, these situations provide an opportunity to examine how linguistic structure re-emerges when the relatively disorganized pidgin is regularized into a *creole* via the language acquisition of young learners who are exposed to it from early childhood. A significant feature of creoles is that they are almost always SVO (Bakker, 2008; McWhorter, 2001). Indeed, SVO is found even when a creole's input languages were SOV (Kouwenberg, 1992).

Although this process is most easily observed in creoles, it is repeated on much slower time scales in natural languages. Languages are dynamic systems that change over centuries in response to various pressures. One systematic aspect of this diachronic change is that, as briefly noted above, languages commonly shift away from SOV, but do not shift toward it except through language contact (Vennemann, 1973). SVO-to-SOV change in Mandarin Chinese has been put forward as one counter-example (Li & Thompson, 1974), but even that claim has been strongly challenged (Sun & Givón, 1985). A recent analysis by Gell-Mann and Ruhlen (2011) showed that SOV languages can become SVO (or, less commonly, OVS and OSV). Meanwhile, SVO languages sometimes become VSO (and vice versa) or VOS (which can also become VSO), but not SOV.

If SOV has a special status because it corresponds to how human cognitive systems tend to order the elements of dynamic events, then what can explain the fact that languages systematically move away from SOV (whether through creolization or through gradual diachronic change)? One clue comes from an asymmetry in the kinds of languages that use *case marking*. Case marking is another way that languages convey relational information (i.e., who did what to whom). Unlike content words, case markers – which are typically suffixes – do not refer to entities, states, or actions; rather, they indicate the role that content words play in an utterance. For example, a case-marking language may attach one suffix to the subject of a sentence, and a different suffix to the object. The relevant asymmetry is that case marking is more common in languages whose preferred order is SOV than in languages whose preferred order is SVO. This pattern is nicely illustrated by data from the World Atlas of Language Structures (http://wals.info), which is a large database that catalogues various linguistic features of the world's languages. It includes data on the case-marking status of 101 SOV languages; of these, 83 (82%) use some form of case marking. Conversely, of the 71 SVO languages for which WALS includes case marking data, only 21 (29%) use some form of case marking. One plausible interpretation of these facts is that case marking performs a function that is more imperative for SOV languages than for SVO languages.

Another clue comes from a more specific pattern of case marking usage. In some languages, case marking is compulsory on all objects. However, many languages exhibit a pattern known as *differential object marking* (Bossong, 1991). In these languages, case marking is used selectively such that objects with more subject-like properties are more likely to be case marked. For example, subjects tend to be definite (e.g. “the woman”), while objects tend to be indefinite (“a box”). More crucially for present purposes, subjects also tend to be human (“the woman”) while objects tend to be non-human (“a box”). Aissen (2003) demonstrated that across languages, reliable hierarchies can be inferred: if a language case-marks inanimate objects, it will also case-mark animate objects; likewise, if a language case-marks animate non-human objects, it will also case-mark human objects. The fact that object animacy is one of the specific triggers for differential object marking indicates that case marking may be especially important for *reversible events*: those where the patient is a plausible agent, such as “a woman lifted a boy”.

Further support for this interpretation comes from another way that languages change across time. Differential object marking systems are most familiar in languages whose case systems are in the process of decay. In languages in general, there is a pressure to reduce phonological content and sometimes, morphology goes along with it (e.g., “iced tea” is referred to by many as “ice tea”). When the meaning of an utterance makes the relationships among referents obvious (e.g. women lift boxes; boxes do not lift women), the pressure to reduce phonology may outweigh the incentive to retain case marking. However, when the meaning of an utterance leaves the relationships among referents ambiguous (e.g. women can lift boys, and boys can lift women), there may be greater benefits to retaining overt case marking. If these benefits outweigh the pressures to let the morphemes erode, a differential object marking system results. If, however, the case system erodes entirely, a language will tend to either re-evolve case marking or shift to another constituent order – usually SVO (Sinnemäki, 2010).

Taken together, these data suggest that, although SOV may be well-suited for describing non-reversible events, it might be less well-suited for describing reversible events. The fact that languages retain case longest for reversible events suggests that it is those events where case is most needed. Just as the gradual loss of case over time leads many SOV languages to slowly shift to SVO, the sudden loss of case in pidgins may be what drives creoles to quickly shift to SVO: in the absence of case marking, SOV is not well-suited for communicating about reversible events.

Still missing, however, is an explanation for why SOV is not well suited for reversible events. Experimentally-elicited pantomime is a useful paradigm for testing this question, because it allows people to communicate about reversible and non-reversible events without being constrained by the grammars of their native language. Participants’ behavior in a pantomime task can therefore provide a window into cognitive or communicative preferences that might otherwise be obscured by the rules of their spoken language grammar. Interestingly, two recent studies have found that participants avoid using SOV to describe reversible events in pantomime. However, these studies give contrasting explanations as to why SOV is not well suited for reversible events.

The first study (Meir et al., 2010) asked native speakers of Hebrew (an SVO language) and Turkish (an SOV language) to describe transitive events in pantomime. They manipulated whether the patient was human or non-human, and found that, although participants used mainly SOV when the patient was non-human, they avoided SOV when the patient was human. Their explanation for this SOV-avoidance was based on the potential for confusability when two agent-like arguments are adjacent, which is a widespread and longstanding intuition in functionalist linguistics (e.g., Vennemann, 1973). For example, in an utterance of the form “woman boy push,” the adjacency of “woman” and “boy” may make them more ambiguous with respect to which is the agent and which is the patient, so that an addressee who encounters this utterance might be at risk for misinterpreting the producer's intended message. Such confusability-based accounts are inherently about the nature of the comprehension process, as of course, producers know the meanings they intend to convey (whether an event is reversible or non-reversible). One possible mechanism that could cause change away from SOV is that the relative confusability of S and O in unmarked SOV utterances leads to communicative inefficiency, which feeds back to producers, leading to linguistic innovations such changing constituent order or using case marking. We will refer to this possibility as the *confusability hypothesis*, and note that it operates primarily through comprehension.

The second study, by Gibson et al. (2013), found a fairly similar pattern of results. They again replicated the observation that native speakers of English (SVO), Japanese (SOV), and Korean (SOV) used mainly SOV to describe non-reversible events in pantomime. To describe reversible events (e.g. woman push boy), English speakers changed from SOV to SVO, although Japanese and Korean speakers remained SOV-dominant, suggesting that native language may have influenced behavior in their pantomime task. However, when asked to describe more complex stimuli (e.g. a man says that a woman pushes a boy), Japanese and Korean speakers did avoid using their native language structure (S[O]V), and used mainly SV[O] instead (where [O] represents the embedded clause), just as English speakers did.

To account for these data, Gibson and colleagues situate their findings in the context of rational communicative behavior over a noisy channel. According to this view, both production and comprehension systems are sensitive to the fact that language transmits information imperfectly. The transmission process is noisy, such that some of the communicative signal is at risk of being corrupted or lost. Therefore, an ideal comprehender should consider both the literal input received as well as the prior likelihood that the input accurately reflects the speaker's intentions. Likewise, on the production side of the equation, an ideal producer should take into account the possibility that some information may be lost in transmission, and should therefore choose a structure that would minimize the communicative consequences of such a loss. Gibson and colleagues argue that in the absence of other cues such as case marking, an ideal producer should avoid using SOV for reversible events (e.g. “woman boy push”), because an omission of either nominal argument could harm communication: an utterance like “woman push” or “boy push” would require a comprehender to guess whether the remaining noun was the agent or the patient. In contrast, SVO order is robust to this concern, since an omission of either nominal still yields an interpretable (if partial) utterance (e.g. “woman push” or “push boy”). They term this account the *noisy-channel hypothesis*.

It its most intuitive sense, the noisy-channel hypothesis explains communicative behavior between a producer and a comprehender. Gibson and colleagues point out that, although there are no comprehenders present in these experiments, producers may construct mental models of what would be difficult for or ambiguous to their addressees, and compensate for this anticipated difficulty by changing constituent order or using other cues (e.g. case marking) when semantics alone do not suffice.

However, the noisy channel can also be interpreted as applying to the producer's own mental representation of events to be described, with the speaker himself serving as the only potential comprehender (Gibson et al., 2013).

In this sense, the noise refers to the robustness of the memory representation of the event to be described. Presumably, if the producer's memory of the event is encoded in a way that involves linear order, then the same logic would apply: mentally encoding the nominal arguments on opposite sides of the verb would yield a less vulnerable representation than mentally encoding them on the same side of the verb. In both senses, the noisy-channel hypothesis emphasizes a producer's drive for maximizing the integrity of a message in the face of possible signal loss or corruption. It predicts that producers should avoid structures that risk information loss, such as having two plausible agents on the same side of an action gesture.

The current study is motivated in part by a discrepancy between the two accounts offered above. Meir et al. (2010) report that when their participants avoided SOV, they commonly switched to using OSV order. This observation seems difficult to reconcile with the confusability hypothesis that they propose: if people avoid SOV because PERSON–PERSON–ACTION sequences would be confusing to a comprehender, then OSV should be just as problematic, since it too involves a PERSON–PERSON–ACTION sequence. OSV order is equally problematic for the noisy channel hypothesis, because it is vulnerable to the same omission problems that render SOV unsuitable for reversible events (both human nominals precede the action). OSV did not occur very frequently in the Gibson et al. data (Gibson, personal communication, 8/26/12); however, given the theoretical significance of this discrepancy, additional replication is warranted.

Therefore, the current study asked native English speakers to describe transitive events in pantomime. We manipulated whether the events were reversible or non-reversible. In Experiment 1, these events were intermixed. In Experiment 2, participants described the non-reversible events first, followed by the reversible events. In Experiment 3, the placement of the reversible events was manipulated between-subjects: they appeared first, last, or mixed. In all cases, we coded constituent order and also looked for other devices that might signal semantic roles, such as case markers.

We expect to replicate previous findings that (a) SOV descriptions are dominant for non-reversible events, but that (b) participants avoid using SOV to describe reversible events. We can then use the full distribution of participants' responses, including the prevalence and distribution of OSV descriptions, to evaluate whether the confusability hypothesis or noisy channel hypothesis can account for the data, or whether a third alternative should be considered.

2. Experiment 1

2.1. Method

2.1.1. Participants—We tested 24 undergraduate students at UC San Diego who reported being monolingual native English speakers. All participants gave consent to participate and be videotaped as part of the study.

2.1.2. Materials—Stimuli consisted of video clips of a human agent (man, woman, boy, or girl) performing a transitive action (kissing, lifting, petting, or pushing) on a patient that was either non-human (ball, box, bike, car, cat, dog) or human (man, woman, boy, or girl). Events where the patient was human were considered reversible; all others were considered non-reversible. (We examined whether animate non-human objects [dog, cat] patterned differently from inanimate objects, but found very little evidence of such differences.) Among reversible events, the patient always differed from the agent in age, sex, or both.

The 61 stimulus events are provided in the Appendix. They were composed of 45 non-reversible events and 16 reversible events. Movies were filmed with a consumer-level digital camcorder in naturalistic settings and were displayed on a Macintosh laptop using PsyScope X software (Cohen, MacWhinney, Flatt, & Provost, 1993; build 53, available from http://psy.ck.sissa.it/).

2.1.3. Design—The manipulation of reversibility was within-subjects; all participants saw all 61 items, which were arranged in a pseudo-random order, with the constraint that consecutive events differed in at least two of the three arguments involved, thus mitigating concerns about potential trial-to-trial carryover or contrast effects. To guard against possible order or learning effects, half of the participants encountered the items in reverse order. Reversible and non-reversible events were mixed throughout the block.

Participants performed three tasks: describing the events in English, describing the events in pantomime, and performing an unrelated filler task that involved describing shapes. Each task had its own dedicated block, and the filler task always separated the English and pantomime tasks, as in Goldin-Meadow So, et al. (2008). However, whereas Goldin-Meadow et al. always began with English and ended with pantomime, we counterbalanced the order of these tasks. (Goldin-Meadow So, et al. (2008) aimed to make the strong demonstration that SOV order was used in pantomime even after those events have just been described in English; however, we counterbalanced task order because we expected that SVO might be more prevalent for reversible events, and we wanted to be able to demonstrate the reversibility effect even when participants had not yet described the events in English.)

2.1.4. Procedure—Participants were told that they would see short video clips, and they were instructed to describe the clip either in English, or in pantomime (i.e. gesture without speech). Practice trials consisted of four videos of events like those shown in the target trials: three non-reversible and one reversible. During the practice trials, participants were encouraged to produce gestures that conveyed all of the major information in each scene, but we very carefully avoided using any directives that mentioned subjects/ agents, objects/ patients, or verbs/actions. The aim was to ensure that on critical trials participants would use gestures for all three constituents; this was largely successful (97.2% contained agent gestures, 99.1% contained patient gestures, 99.9% contained action gestures, not counting excluded trials, or those classified as “ambiguous” or “simultaneous”).

Following the 4 practice trials, participants began the 61 critical trials. On each trial, a short video clip would play. Upon its completion, participants described the event in English to a sound recorder or in gesture to a digital camcorder. The experimenter remained in the room but did not interact with the participants, and was often hidden from view. Participants were free to replay an event as often as desired. When the participants finished describing an event, they clicked a button to proceed to the next trial.

2.1.5. Coding—Subjects' gestures were transcribed by two trained coders who identified each gesture's referent as subject, verb, object, or other. Multiple consecutive gestures for the same referent were considered as belonging to the same constituent. For example, the string "TALL LONG-HAIR WHELLS PEDALS HANDLEBARS PUSH" would be parsed as SOV (woman, bicycle, push). However, if the string was non-consecutive, a repetition would be noted. For example, "TALL LONG-HAIR WHELLS PEDALS PUSH HANDLEBARS" would be coded as SOVO (woman bicycle push bicycle). In the absence of any principled way to determine phrase or utterance boundaries in pantomime, everything that the participant produced was counted as a single utterance unless there was a pause of more than 2 s or the string was interrupted by the participant replaying the video. In these cases, the most complete string containing an action gesture was coded. Gestures classified as "other" were ignored in determining constituent order; these mainly contained information about the environmental surroundings of the scene. If it was not possible to determine the referent of a gesture, the trial was coded as "ambiguous". If participants produced gestures that referred to more than one constituent at the same time, such that it was not possible to compute order of mention, it was considered "simultaneous" (for example, simultaneously producing two inverted "V" handshapes to represent two people standing near each other). Orders that accounted for less than 2% of both non-reversible and reversible events were considered "rare" and left unlabeled.

Coders were not blind to the experimental manipulations. However, they were blind to one another's ratings, and agreed on 1104 of the 1464 utterances (75.6%). In cases of disagreement, the first author coded the trial blind to the raters' responses. If this resulted in 2 of 3 coders agreeing, the trial was included. If all three coders disagreed, the trial was excluded from analysis (88 trials = 6%; labeled "excluded" in Fig. 1).

2.2. Results

2.2.1. Constituent order in English—As expected, English descriptions from all participants were over 98% SVO for both reversible and non-reversible events, and will not be discussed further.

2.2.2. Constituent order in pantomime

2.2.2.1. Group results: Fig. 1 presents the distribution of constituent orders in participants' pantomimes of non-reversible (left) and reversible (right) events. Among non-reversible events, SOV was the most common order, accounting for 50.9% of utterances; OV descriptions, which are consistent with SOV, constituted another 2.9% of utterances. SVO was roughly half as common, accounting for 27.5%. However, among reversible events, these proportions were reversed. SOV shrank to only 12.5% (Region A), while SVO became the most common order with 35.4% (Region B). OSV and OSVO grew from a combined 4.3% in non-reversibles to 11.5% in reversibles. SOSV and SOSVO also grew from a combined 1.9% in non-reversibles to 15.6% in reversibles. These four orders are shown together in Region D. The increase in Region D was signifi-cant across subjects by a paired t-test [$t(23) = 4.86$, $p < .001$].

The only other obvious change between non-reversible and reversible conditions was an increase in the percentage of excluded trials. This is due mainly to the fact that many participants produced highly complex utterances on reversible trials; the more components an utterance had, the less likely it was that at least 2 of 3 coders were in complete agreement. These trials are depicted in Region E, together with those classified as ambiguous, simultaneous, or rare.

To quantify the decrease in SOV, we followed Goldin-Meadow So, et al. (2008) by computing the proportion of each participant's utterances that were consistent with SOV (i.e. SV, OV, and SOV). A within-subjects t-test showed that participants used significantly fewer SOV-consistent orders for reversible than for non-reversible events [$t(23) = 6.18$, $p < .001$].

2.2.2.2. Individual results: The group-level results above were echoed by the individual data. SOV became less common from non-reversible to reversible events in 20 participants, increased in only 1, and was absent or nearly so for the remaining 3. This decrease in SOV for reversible events was significant by a sign test ($p < .001$). We also identified the orders that each participant used most often for non-reversible events and for reversible events. For non-reversible events, SOV was dominant in 17 of 24 participants. For reversible events, only 3 participants remained SOV dominant.

2.2.3. "Case Marking" in pantomime—In the current data, we observed gestures that functioned like case markers. They had no referential content, but indicated which role other gestures played in the utterance. They most commonly took the form of gestures where "1" indicated the agent and "2" indicated the patient. Some reversible utterances began with a "2" gesture, which we interpreted as signaling that the event to-be-described involved 2 people. In the analyses of constituent order discussed above, these gestures were treated as repetitions of the referent; that is, a string such as "1 MAN 2 WOMAN 1 LIFT 2" would be coded as SOSVO.

Case marking was found with a variety of word orders; its prevalence among SOV and Region-D orders was no different than would be expected by chance (SOV: $\chi^2(1) = 1.36$, $p = .24$; Region D: $\chi^2(1) = 2.16$, $p = .14$). Interestingly, the prevalence of case marking on reversible SVO trials was significantly less than would be expected by chance (SVO: $\chi^2(1) = 13.1$, $p < .001$). These data are displayed in Fig. 2.

2.2.3.1. Group results: We coded the trials dichotomously for the presence versus absence of these devices (inter-rater reliability = 95.2% after 2 coders; 100% after 3) and found that gestures resembling case marking were significantly more common for reversible (16.4%) than non-reversible events (2.8%; $t(23) = 3.08$, $p < .001$).

2.2.3.2. Individual results: Gestures that functioned like case markers were used by 10 of the 24 participants, appearing anywhere from 1 to 39 times per individual. In each of these 10 participants, the proportion of reversible events with case marking gestures was greater than the proportion of non-reversible events with case marking gestures. Again, this pattern is significant by a sign test ($p < .01$). Thus, while not universal, this type of gesture is by no means an isolated phenomenon; we therefore examine it more systematically in Experiments 2 and 3.

2.3. Discussion

The results of Experiment 1 replicate the central findings that have been reported in the literature: when describing non-reversible events in pantomime, participants tend to use SOV, but when describing reversible events, they tend to avoid SOV. Thus, there is strong consensus about the existence of a cognitive bias against using SOV to describe reversible events. However, the exact nature of this bias is less clear.

Both the confusability hypothesis (Meir et al., 2010) and the noisy-channel hypothesis (Gibson et al., 2013) rely on the notion that reversible utterances contain potential confusability, either for a (hypothetical) addressee or for the producers themselves. That is, in a PERSON–PERSON–ACTION utterance, it may be more difficult to determine which person was the agent. Gibson et al. (2013) make this explicit, stating (in the abstract), "The noisy-channel hypothesis predicts a shift from the default SOV order to SVO order for semantically reversible events, where potential ambiguity arises in SOV order because two plausible agents appear on the same side of the verb."

These hypotheses make the specific prediction that utterances with S and O on the same side of V should be less common for reversible events than for non-reversible events. This prediction finds support insofar as SOV became less common for reversible events (Fig. 1, Region A), and SVO became more common (Fig. 1, Region B). However, it fails to account for our finding that a number of other orders with S and O on the same side of the verb did not decrease, but instead increased for reversible events, including OSV, OSVO, SOSV, and SOSVO (Fig. 1, Region D). Similar findings were also reported by Meir et al. (2010), who observed a marked increase in OSV for reversible events. Both the confusability hypothesis and the noisy-channel hypothesis predict all of these orders to decrease for reversible events, and yet they became significantly more common. This invites us to consider an alternative hypothesis that might account for the data.

To be more specific, note first that there was a consistent difference in how participants pantomimed human versus non-human entities. For human entities, participants usually took on the role of the entity. For example, to gesture "man," some male participants pointed to themselves, while other participants pantomimed the familiar flexed-biceps pose, and still others adopted a particular posture. These are all ways in which they described a human entity by embodying its role. In contrast, for non-human entities, participants typically did not take on the role of the entity. For example, to pantomime "box," participants did not take on the role of the box; they usually just gestured out a box shape in space. Critically, when participants pantomimed actions, they almost invariably took on the role of the agent performing the action. To pantomime lifting, for example, participants acted as if they themselves were the agent doing the lifting. To describe a non-reversible event (e.g. a woman lifting a box) using SOV order, participants would generally adopt the role of the agent (long hair), then produce a gesture for the box without adopting any role. In this case, the participant does not need to do anything special to re-inhabit the role of agent in time to produce the action gesture.

In contrast, using SOV for reversible events (e.g. a man lifting a woman) is likely to entail a *role conflict* between O and V. For example, if a participant described a reversible event using SOV order, she or he would first adopt the role of the agent (flexing muscles), then the patient (long hair). The participant is now in the patient role but is ready to produce the action, which requires him or her to be in the agent role. If the participant were to produce an action gesture without first doing something to switch back into the agent role, it may "feel" to him or her as if it is the patient and not the agent that is carrying out the action. It is this that we refer to as role conflict.

We suggest that participants' drive for avoiding role conflict in production is what best accounts for their behavior. Some participants avoided role conflict by repeating an agent gesture before the action (e.g. SOSV), others solved it by moving O to the front (e.g. OSV), and the most common solution was to move O to the end (SVO). Some also used gestures like "1" and "2" to overtly mark the difference between the two human entities.

A related observation has been made by Meir et al. (2007), who noticed that verbs in many (if not all) sign languages exhibit a pattern they call "body-as-subject". They noticed that in these languages, the signer's body plays a privileged role during the articulation of verbs: it represents the highest-ranking thematic role in the event. For transitive events like the ones we use here, the highest-ranking role is typically the agent. Meir et al. (2007) further suggest that body-as-subject is the first type of verb agreement that a new sign language will evolve. A novel contribution of the present data is that we find that a similar pattern (body-as-agent) is already present even in nonlinguistic pantomime.[1] Furthermore, the present results suggest that role conflict has a strong impact on constituent order in elicited pantomime. This leads to the prediction that body-as-subject may also have consequences for constituent order in emerging sign languages. This possibility has not yet been explored in the literature (but see Hall, in preparation). We will return to these ideas in the general discussion; for now, we note that pantomimers, like signers, tend to use their bodies to take on the agent role when gesturing transitive actions. If pantomimers used SOV order to describe reversible events, this would likely lead to role conflicts. Avoiding these conflicts, then, may explain the distribution of constituent orders for reversible events.

All three hypotheses (confusability, noisy-channel, and role conflict) can account for the decrease in SOV and increase in SVO, but only the role conflict hypothesis can also explain increases in other orders such as those in Region D of Fig. 1, all of which avoid having the patient immediately precede the action. In contrast, the only order that is consistent with the confusability and noisy-channel hypotheses but not with role conflict is SVOV (Fig. 1, Region C), and it became slightly less frequent in reversible events than it had been in non-reversible events. This account is admittedly post hoc, and so it might simply describe the one sample of data we collected; our next goal is to replicate the effect. If the role conflict account is correct, we should see that participants in Experiment 2 also avoid SOV for reversible events, but that other orders like OSV, OSVO, SOSV, and SOSVO should not be similarly penalized.

[1]We make no claim about the status of "Subject" as an abstract syntactic category in pantomime.

In addition, Experiment 2 is designed to further restrict the possible influence of English on participants' responses. We observed that participants who began by describing the events in English used SVO 17% more in pantomime than participants who began with the pantomime task. Importantly, this tendency did not interact with reversibility [$F(1,22) = 33$, $p = .57$], so that our main observations stand unchanged. It does, however, suggest that asking participants to describe the events in English can influence their behavior on a subsequent pantomime task. Insofar as one of the key results of the reversibility manipulation was an increase in SVO, we want to guard against the possibility that it arose because participants had previously described the events in English. Therefore, all participants in Experiment 2 performed the pantomime task first, and then described the events in English.

A further concern is that the magnitude of the SOV bias in our non-reversible events was somewhat smaller than that reported by Goldin-Meadow So, et al. (2008); on those non-reversible trials, our participants used more SVO than theirs did. Because we used different events and more stimuli, it is possible that the increased SVO we observed is attributable to some property of our items.[2] Alternatively, it is possible that the pressure to avoid SOV for reversible events was so strong that it spilled over and influenced the way that participants described non-reversible events, biasing them toward SVO. To distinguish these possibilities, Experiment 2 presented all of the non-reversible events first, with the reversible events all appearing at the end of the session. This manipulation makes it impossible for the reversible events to influence how participants described the non-reversible events. If participants' descriptions of reversible events attenuated SOV and increased SVO for the non-reversible events in Experiment 1, we should observe relatively more SOV and relatively less SVO for the non-reversible events in Experiment 2. One consequence of this manipulation could be an attenuation of the SOV-avoidance for reversibles that we observed in Experiment 1; after 45 non-reversible trials, participants might become accustomed to their particular way of describing events. However, any effects of reversibility that we do see could thus be seen as even more robust in this design.

3. Experiment 2

3.1. Method

3.1.1. Participants—We tested 12 undergraduate students at UC San Diego who reported being monolingual native English speakers. All participants gave consent to participate and be videotaped as part of the study.

3.1.2. Materials—The stimuli were the same as those in Experiment 1.

3.1.3. Design—All participants described events in pantomime first and then described the events in English. There was no filler task.

[2]In pilot testing with the actual items from Goldin-Meadow, So, et al. (2008), we observed an SOV bias of the same magnitude as they report. Gibson et al. (2013) also found the same result with the Goldin-Meadow et al. stimuli, but an attenuated SOV bias in his new stimuli (personal communication, 8/26/12).

To test whether our non-reversible items were capable of eliciting a stronger SOV bias, we designed a new pseudo-random order in which the 45 non-reversible events appeared first, followed by the 16 reversible events. As before, the only constraint was that consecutive trials always differed in at least two elements. This design allows a more straightforward comparison between our stimuli and those of Goldin-Meadow So, et al. (2008), which were all non-reversible.

3.1.4. Procedure—The only additional difference from Experiment 1 was changing the four practice trials to be all non-reversible events that were chosen with permission from the items used by Goldin-Meadow So, et al. (2008).

3.1.5. Coding—We used the same coding procedures as in Experiment 1.

3.2. Results

3.2.1. English—As before, the English results were 96.2% SVO and do not merit further discussion.

3.2.2. Constituent order in pantomime

3.2.2.1. Group results: Fig. 3 presents the distribution of constituent orders in participants' pantomimes of non-reversible (left) and reversible (right) events. We again found an SOV bias for non-reversible events, which – together with OV – accounted for 57.8% of trials. SVO was again the second most common order, but accounted for only 14.3% of trials: roughly one fourth the size of the SOV bias. This SOV bias was numerically greater in this experiment (blocked) than in the previous experiment (mixed). We again found that participants strongly avoided SOV for reversible events, where they accounted for only 2.6% of reversible trials (Region A). Likewise, SVO increased from 14.3% in non-reversibles to 38% in reversibles (Region B). Orders that would be predicted to decrease by confusability-based accounts (Gibson et al., 2013; Meir et al., 2010) did not do so. Instead, OSV and OSVO together increased from 5.9% to 13%, with SOSV and SOSVO also increasing together from 4.1% to 10.4% (Region D). The increase in Region D was statistically significant across subjects by a paired *t*-test [$t(10) = 2.31$, $p < .05$]. (One participant's reversible descriptions contained only simultaneous and excluded orders; therefore, this participant did not contribute to this analysis or the one below.)

As in Experiment 1, we quantified the decrease in SOV by using a paired t-test to compare the proportion of each participant's utterances that were consistent with SOV (i.e. SV, OV, and SOV) for non-reversible and reversible events. This test was significant [$t(10) = 5.85$, $p < .001$].

3.2.2.2. Individual results: Again, the individual data yield the same picture as the group data. SOV became less frequent from non-reversible to reversible events in every participant. This decrease is significant by a sign test ($p < .001$). While 8 of 12 participants were SOV-dominant for non-reversible events (i.e. SOV was their most common constituent order), 0 remained SOV-dominant for reversible events.

3.2.3. Case marking

3.2.3.1. Group results: As in Experiment 1, we observed gestures that functioned like case markers. We coded trials dichotomously for the presence versus absence of devices that carried no referential content except to indicate an- other gesture's semantic role (inter-rater reliability = 97.7% after 2 coders; 100% after 3). Again, we found that gestures resembling case marking were more common for reversible (22.9%) than non-reversible events (0.3%). Despite a smaller number of observations and high variability, this effect was significant by a 1-tailed *t*-test [$t(11) = 2.05$, 1-talied $p = .033$]. These data are displayed in Fig. 4.

Case marking was again found with a variety of word orders. As in Experiment 1, its prevalence among SOV was no different than would be expected by chance (SOV: $\chi^2(1) = 1.0$, $p = .32$), while the prevalence of case marking among reversible SVO trials was significantly less than would be expected by chance (SVO: $\chi^2(1) = 12.25$, $p < .001$). Unlike Experiment 1, case marking as also less common than expected among Region D orders ($\chi^2(1) = 5.76$, $p < .02$).

3.2.3.2. Individual results: Gestures that functioned like case markers were found in 6 of 12 participants, appearing anywhere from 1 to 16 times per participant. They were more common in reversible events for 5 participants, and equal (0%) in 6; however, 1 participant produced 2 instances of case marking on non-reversible trials and 0 on reversible trials. With this small number of observations, those two trials rendered the sign test non-significant.

3.3. Discussion

Experiment 2 had three main goals: (1) to replicate Experiment 1 while limiting the influence of English; (2) to test the role conflict account of SOV avoidance; and (3) to test whether the presence of reversible events in Experiment 1 influenced the ways in which participants described the non-reversible events.

The first goal was clearly achieved. Participants in both experiments were SOV-dominant for non-reversible events, but avoided SOV for reversible events, even after having seen a string of 45 consecutive non-reversible events. Gestures that functioned like case markers were present in both experiments; this phenomenon was numerically stronger in Experiment 2, but the smaller sample size weakened our power to detect a significant effect.

The second goal was to test competing accounts of the above effects: confusability, noisy-channel, and role conflict. Both confusability and noisy-channel accounts predict that all constituent orders with S and O on the same side of V should become proportionally less common for reversible events. The role conflict account posits that only a subset of those should be penalized: those orders where a human object is followed by a verb gesture. Both accounts correctly predict a decrease in SOV and an increase in SVO. Therefore, the critical test is to examine orders with S and O gestures on the same side of V, but where O is not followed by V (e.g. OSV, OSVO, SOSV, SOSVO, etc.). Here, the results once again favored the role conflict account: Participants did not avoid those orders; in fact, they became significantly more common, as shown in Fig. 3, Region D. The only order that is uniquely predicted to increase by confusability is SVOV, whose increase from 2.6% to 3.7%

is modest (Fig. 3, Region B). These results strongly resemble those of Experiment 1, suggesting that this pattern does not merely reflect random differences between individuals. Still, additional replication would further strengthen the case.

Experiment 2's third main goal was to explore an unexpected aspect of Experiment 1: namely, that the SOV bias was weaker than that reported by Goldin-Meadow So, et al. (2008), and SVO figured much more prominently in our non-reversible events than in theirs. It may have been that the presence of reversible events (which were mixed throughout the block in Experiment 1) influenced the way participants described the non-reversible events. If so, then moving all the reversible events to the end of the block should have resulted in more SOV and less SVO for the non-reversible events in Experiment 2 than in Experiment 1. This was in fact the case: among non-reversible events, the SOV bias was stronger in Experiment 2 (blocked, 59.6%) than in Experiment 1 (mixed, 54.4%). Similarly, SVO was less common in Experiment 2 (blocked, 14.3%) than in Experiment 1 (mixed, 27.5%). If these differences can be replicated, they could constitute the first (to our knowledge) empirical demonstration that the need to communicate about reversible events causes constituent order to shift away from SOV and toward SVO, even for non-reversible events.

However, there are several reasons to be cautious before reaching such a conclusion. First, these differences (especially the comparison of the SOV bias) are not large. Another limitation is that they are based on between-experiment comparisons, which admit the possibility of uncontrolled differences between studies. These differences would be more convincing if obtained via random assignment in a single experiment. A third limitation is that we cannot distinguish effects of blocking versus mixing the reversible events from those of moving the English block to the end of the session: the differences we observed could be attributed to one, the other, or both changes. Experiment 3 was designed to distinguish these possibilities by manipulating where the reversible events appeared during the session, and randomly assigning participants to one of three conditions: reversibles-last (like Experiment 2), reversibles-mixed (like Experiment 1), or reversibles-first, where the presence reversible events might exert an even stronger influence on how participants describe non-reversible events.

4. Experiment 3

To determine whether the presence of reversible events influences the way participants describe non-reversible events, Experiment 3 manipulated (between subjects) the positioning of the reversible events over the course of the experiment. Based on the results of Experiment 1 and 2, we predicted that the prevalence of SOV for non-reversible events would be greatest when reversible events had not yet occurred (reversibles-last), less when reversible events are mixed throughout the block (reversibles-mixed), and least when the block begins with all of the reversible events (reversibles-first).

4.1. Method

4.1.1. Participants—We tested 36 undergraduate students at UC San Diego who reported being monolingual native English speakers. All participants gave consent to participate and be videotaped as part of the study. They were randomly assigned to one of the three conditions, yielding 12 participants in each group.

4.1.2. Materials—Stimuli were the same as those in Experiments 1 and 2.

4.1.3. Design—The only changes to the design were the between-subject manipulation of the position of the reversibles and removing English from the experiment altogether. The reversibles-last group (n = 12) saw the same order as the participants in Experiment 2, which began with the 45 non-reversible events and finished with the 16 reversible events. The reversibles-mixed group (n = 12) saw one of the orders that we used in Experiment 1, with reversible events mixed throughout the testing session. The reversibles-first group (n = 12) saw the same order as the reversibles-last group, except that the 16 reversible events came at the beginning of the experiment instead of the end.

4.1.4. Procedure—The only change to the procedure was in the practice trials. We wanted all participants to experience the same practice trials, but because some groups would be starting with reversibles and others with non-reversibles, we could not use any transitive events during practice. Instead, the practice consisted of 6 intransitive events (e.g. a woman waving), half of which also included a locative element (a girl walking toward a car). These materials were borrowed with permission from the original materials used by Goldin-Meadow So, et al. (2008). Locatives were included as a third element of some videos to encourage participants on critical trials to use gestures for all three arguments, which indeed occurred (82.3% contained agent gestures, 93.5% contained patient gestures, 99.8% contained action gestures).

4.1.5. Coding—We used the same coding procedures as in Experiments 1 and 2.

4.2. Results

4.2.1. Constituent order

4.2.1.1. Between-subjects results: The presence of reversible events did not systematically influence the frequency with which participants used SOV to describe non-reversible events. We followed Goldin-Meadow So, et al. (2008) in classifying each utterance as either consistent with SOV (SOV, OV, and SV) or not (anything else), and submitted the resulting proportions to a 2 × 3 mixed analysis of variance (ANOVA) with reversibility (reversible, non-reversible) as a within-subjects factor and group (reversibles-last, reversibles-mixed, reversibles-first) as a between-subjects factor. There was no main effect of group [$F(2,33) = .32$, $p = .73$] and no reversibility x group interaction [$F(2,33) = .69$, $p = .51$]. We used a planned contrast to test for linear trend (reversibles-last > reversibles-mixed > reversibles-first), but this too was far from significant [$F(1,33) = .59$, $p = .45$].

4.2.1.2. Within-subjects results: The effect of reversibility is evident in the contrast between the left vs. right member of each pair of columns in Fig. 5. In each case, participants used SOV much less for reversible events than for non-reversible events (Region A). This decrease was significant in the ANOVA above [$F(1,33) = 78.09$, $p < .001$] and by a sign test across individuals (34/36 decreased, $p < .001$).

As in the previous two experiments, orders with both S and O gestures on the same side of V did not become less common for reversible events (Fig. 5, Region D). Instead, a 2 3 mixed ANOVA (designed as above) found a significant increase in Region D for reversible events [$F(1,33) = 8.62$, $p < .01$], and this effect did not vary across groups: there was no main effect of group [$F(2,33) = 0.00$, $p = .99$] and no interaction [$F(2,33) = .10$, $p = .91$].

Collapsing across groups, OSV and OSVO increased from 7.4% in non-reversibles to 15.1% in reversibles. SOSV and SOSVO increased from 6.0% to 10.1%. The most common order for reversible events was SVO, which increased from 16.9% to 25.9% (Region C), collapsing across groups. SVOV, the only order uniquely consistent with the confusability hypothesis, increased from 1% to 1.7% (Region B), collapsing across groups.

4.2.1.3. Individual results: In the absence of a main effect of group, we discuss the data from all 36 individuals together. SOV became less frequent from non-reversible to reversible events in 34 participants, which is significant by a sign test ($p < .001$). Of the 36 participants, 23 were SOV-dominant for non-reversible events (i.e. SOV was their most common constituent order), with only 3 remaining SOV-dominant for reversible events.

4.2.2. Case marking

4.2.2.1. Group results: As in Experiments 1 and 2, we observed gestures that functioned like case markers, and found that they were more common for reversible events than for non-reversible events. We computed the proportion of trials on which each participant used gestures that functioned like case markers. We submitted these to the same 2 3 ANOVA described above and once again found that case marking was more common for reversible events than for non-reversible events [$F(1,33) = 10.56$, $p < .01$]. Interestingly, there was also a trend toward a main effect of group [$F(2,33) = 2.82$, $p = .07$]. As shown in Fig. 6, case marking was relatively rare in the reversibles-last group, and restricted to reversible events only. In the reversibles-mixed group, it became more common but was still restricted to reversible events. Case marking was most common in the reversibles-first group, where it began to be used even for non-reversible trials. A post hoc test for linear trend was significant [$F(1,33) = 5.54$, $p < .03$].

To analyze the relationship between case marking and constituent order, we collapsed across the manipulation of whether reversible events appeared first, last, or mixed. As in both Experiments 1 and 2, the prevalence of case marking among reversible SVO trials was significantly less than would be expected by chance (SVO: $\chi^2(1) = 20.82$, $p < .001$). Unlike both previous experiments, case marking was also less common than chance for reversible SOV utterances ($\chi^2(1) = 4.35$, $p < .04$). Also in contrast to both previous experiments, case marking among Region D orders was more common than expected ($\chi^2(1) = 26.47$, $p < .001$).

4.2.2.2. Individual results: Gestures that functioned as case marking were found in 15 of 36 participants, appearing anywhere from 1 to 61 times per participant. They were proportionally more common in reversible events for 14 participants, less common for reversibles in 1, and tied (0% or 100%) in the remaining 21. This pattern is significant by a sign test ($p < .001$).

4.3. Discussion

The main purpose of Experiment 3 was to test whether the presence of reversible events would influence the way participants described non-reversible events. Based on a comparison of Experiments 1 and 2, we expected to see such effects on constituent order, but did not find them. However, we did find such evidence in the frequency of case marking gestures. Placing reversible events earlier tended to lead to more case marking on both reversible and non-reversible events. These data are consistent with observations from the linguistics literature that in many languages, reversible events are more likely to be case-marked than non-reversible events. As noted in the introduction, these systems, known as Differential Object Marking systems, are most widely observed in languages whose case systems have begun to decay, such that reversible events are the ones that retain case marking the longest. However, systems that begin as differential object marking will sometimes expand to become “consistent object marking” systems, where all types of objects receive overt case marking (Aissen, 2003; Bossong, 1991). The present data are, to our knowledge, among the first empirical demonstrations that even speakers of languages without case systems feel a pressure to use additional devices to describe reversible events, and that the need to communicate about reversible events can drive the spread of case marking to non-reversible events. Gibson et al. (2013) observed behaviors that they analyzed as being analogous to case marking. They noticed that participants sometimes located gestures in contrasting regions of space, and used these spatial locations to help convey who did what to whom. They argue that this pattern of “spatial marking” performs a function similar to case marking in spoken languages, and find that it too is more common among reversible events than non-reversible events, and that SVO utterances were less likely to use this device. Thus, although the form of the marking behavior between the present data (numerical affixes) differs from what Gibson et al. observed (spatial marking), both sets of results highlight the role of cognition in driving the emergence of devices for marking argument structure. It appears that the same pressures that drive these long-term changes in a language over time are also at work in the minds of our participants, whose native language does not use a case system.

Experiment 3 also replicated the main findings of Experiments 1 and 2. First, participants in all conditions avoided using SOV order for reversible events. Second, their alternative constituent orders are more consistent with our role conflict account than with previous accounts. Whereas both the confusability hypothesis and noisy-channel hypothesis predict that orders like OSV, OSVO, SOSV, and SOSVO should also be avoided for reversible events, the role-conflict hypothesis predicts that they should actually be acceptable solutions to the problem of having a human object gesture followed by a verb gesture. The data support the latter view.

5. General discussion

In three experiments, we asked native English speakers to describe simple transitive events in gesture without speaking. When these events involved a human agent and a nonhuman patient (non-reversible), the most common constituent order was SOV. However, when the events involved both a human agent and a human patient, participants reliably avoided SOV in favor other constituent orders. These patterns are consistent with findings from several recent studies using similar methods (non-reversible events: Goldin-Meadow So, et al. (2008), Langus & Nespor, 2010; reversible events: Gibson et al., 2013; Meir et al., 2010). However, we offer a different interpretation of these patterns: one that primarily implicates constraints on production. After first reviewing these contrasting accounts, we then discuss the extent to which our hypothesis can account for attested patterns in the world's languages, both spoken and signed.

5.1. Comprehension, production models of comprehension, and production

The idea that the reversible events may require additional linguistic devices is not new. It has long been recognized that a key function of morphosyntax is to guide the interpretation of utterances that cannot be interpreted based on semantics alone – that is, reversible events. Traditional explanations generally assume that what makes SOV problematic is the potential for confusability when two human nominals both precede the verb. In so doing, such views implicitly place the locus of the constraint either on addressees, or on producers’ mental models of what would create difficulty for addressees.

One problem with confusability-based accounts (e.g. Meir et al., 2010) is that they rest on an assumption that remains largely untested: namely, that comprehenders experience processing difficulty when they encounter a reversible utterance in SOV order. In a separate study, we addressed this question by asking speakers of English (SVO) and Turkish (SOV) to watch gestured events and to provide a subjective “goodness” rating. The stimuli varied in constituent order and reversibility; nonetheless, both English and Turkish comprehenders rated SOV as equally good in reversible and non-reversible events (Hall, Ferreira, & Mayberry, 2011). Though it is less convincing to argue from a null effect, approaches that attribute production behavior to constraints on comprehension would be better served if positive evidence regarding comprehension preferences were available.

Even if comprehenders do not experience difficulty understanding reversible SOV sequences, producers might still avoid reversible SOV sequences anyway, due to the risk of information loss during transmission: either to an interlocutor, or in the strength of the producer's own memory representation of the event. If either nominal argument of a PERSON–PERSON–ACTION sequence is lost, the resulting utterance (PERSON–ACTION) could mean either SV or OV. However, SVO utterances are robust to this concern, since deletion of one nominal argument would yield either PERSON–ACTION or ACTION–PERSON, which are unambiguously SV and VO, respectively. This is a core feature of the noisy channel hypothesis (Gibson et al., 2013). Although the noisy-channel hypothesis finds support in recent studies of language comprehension (Levy, 2008; Levy, Bicknell, Slattery, & Rayner, 2009), it is more difficult to reconcile with extant approaches in language production research. To the extent that it relies on production mechanisms to accommodate the vulnerabilities of comprehension mechanisms, the noisy-channel hypothesis is inconsistent with approaches to language production that view production vulnerabilities themselves as especially influential on production (Ferreira, 2008). Still, it is possible that producers avoid SOV in order to minimize information loss in their own memory representations of the events. However, this would require us to assume that the memory representation is itself encoded in a way that relies on linear order, rather than in a more holistic or imagistic code. It is also worth noting that participants in the present experiments were not under any external working memory load, and if they were uncertain about what happened in the event they were free to replay the stimulus video. Thus, it seems likely that constraints on a producer's memory representations of the events contribute only weakly, if at all, to the present findings.

An additional challenge to both confusability and noisy-channel accounts is the observation that orders such as OSV, SOSV, and SOSVO become more common for reversible events. Both the confusability hypothesis and the noisy-channel hypothesis predict that sequences like these, where both human nominals precede the action gesture, should be just as problematic as SOV for reversible events, and for the same reasons. From a comprehension-based perspective, PERSON–PERSON–ACTION sequences are by definition ambiguous between SOV and OSV. From a noisy-channel perspective, sequences like OSV are vulnerable to the same transmission risks as SOV sequences are. Thus, the fact that such orders do not decrease for reversible events, but rather increase (Figs. 1, 3 and 5, Region D) is problematic for both the confusability and noisy-channel hypotheses.

An alternative interpretation, one that is not subject to the above difficulties, is that the participants' behavior was driven mainly by a constraint against *role conflict* in production. This conflict occurs because participants commonly take on the roles of both human agents and patients, but action gestures require the participant to be in the agent role. This, in turn, is because when participants denote the actions of kissing, lifting, petting, and pushing, they generally do so by using their own bodies as if they were the agent. According to this view, the only constituent orders which should be problematic for reversible events are those where O is followed immediately by V. Orders like SVO, OSV, SOSV, and SOSVO avoid the problem by ensuring that S appears before V.

Note that this explanation is operative during production. The problem is not that the sequence man woman lift is produced but potentially ambiguous to an addressee; rather, the problem is that the producer detects a potential mismatch between the intended agent of the action (man) and the most recently adopted role (woman), and so decides against producing the action gesture without adding any additional cues. This does not mean that confusability and noisy-channel processes play no role in how these processes unfold in natural languages; such possibilities remain largely untested. It does suggest, however, that constraints on production may be responsible for more aspects of language structure than previously thought.

5.2. Proto-case-marking in pantomime?

Another systematic pattern that we observed in the data was that some participants began to use gestures that functioned like case markers. That is, they did not refer to any real-world referent; instead, they signaled the role that another gesture played in the event. These gestures were more common for reversible events than for non-reversible events, which strongly resembles differential object marking in the languages of the world. One difference is that in our data, these gestures were not especially more common with SOV or Region-D sequences, as they are in spoken languages; instead, the prevalence of case marking with these orders was variable across our three experiments. However, one significant parallel is that case marking gestures were especially uncommon in SVO sequences, just as case marking is rare in SVO languages. This pattern, which was constant across all three experiments, constitutes evidence that case marking and SVO order are independent solutions to the same problem (semantic reversibility), and once you have one solution, the other is not necessary.

Finally, the above analyses implicitly assumed that all instances of SOV involved role conflict, because of the sequence O–V with a human O. However, it should be noted that some reversible trials that were coded as SOV did in fact satisfy the role conflict constraint, despite the fact that O and V were produced in sequence. One way that participants could avoid role conflict even in SOV descriptions was to avoid taking on the role of the human patient (e.g. referring to the patient by tracing the outline of a body in space, rather than referring to their own body). This accounted for 55 of the 93 reversible trials that were coded as SOV above (59%). But even when participants did take on the role of patient with their own bodies, they could use SOV and still avoid role conflict provided that they established the agent in one location, the patient in another, and then shifted back into the agent's space before producing the action gesture, even without producing any overt repetition of an agent gesture. Spatial marking of this sort was observed on 8/93 reversible SOV trials (9%). This strategy was also observed by Gibson et al. (2013), who noted that exploiting space in this way might perform the same linguistic function that case marking serves in spoken languages. Natural sign languages do not exhibit the kind of affixing that we observed in our participants (e.g. numerical gestures 1 and 2); perhaps over generations, this spatial marking strategy proves to be better suited for communication. Interestingly, Fischer (1975) observed this type of SOV structure in old American Sign Language (ASL), but noted that this strategy is somewhat inefficient because it requires an extra transitional movement between O and V. She then used written transcriptions of signed narratives to make that case that in fact old ASL had SOV structure, but argued that modern ASL has transitioned to using OSV and SVO for these types of reversible events precisely because OSV and SVO avoid this extra transitional movement. The fact that we see naïve participants behaving similarly suggests that the factors involved are not specific to being deaf or having experience with sign language, but are grounded in aspects of cognition that are broadly shared, and potentially universal.

5.3. Is role conflict modality-specific?

A key question concerns whether the role conflict hypothesis is specific to the manual modality, or if it also applies to spoken language. Given the parallels between the patterns attested in pantomime and those in natural language, there are three logical possibilities, discussed in turn below.

The first possibility is that the apparent correspondence across modalities is coincidental: the patterns are the result of independent mechanisms. It will always be difficult to rule out the possibility that independent mechanisms give rise to similar outcomes. Therefore, if simply on the grounds of parsimony, such views should be adopted only after other explanations have been exhausted.

The second possibility is that the cross-modal correspondences are due to mechanisms that are related but not identical. Patterns in pantomime and speech may resemble each other due to mechanisms that are distinct, but within the same family. For example, although our proposed role conflict constraint may not apply directly to speech, other constraints on production may still disfavor unmarked SOV sequences in speech just as in pantomime. For example, assume that the speaker's goal is to describe an event where a woman pushed a man. To the speaker, an unmarked SOV sequence such as “the woman the man pushed” might be dispreferred because there is a potential agent (man) intervening between the real agent (woman) and the action. Therefore, it may seem to the speaker as if he or she is momentarily producing an incorrect utterance (“the man pushed”).

A stronger instance of this pattern might occur in well-known local coherence sentences like, “The coach smiled at the player tossed a Frisbee.” Although difficult to understand, this sentence is grammatical; it is a reduced form of a relative clause (“The coach smiled at the player [who was] tossed a Frisbee”). These sentences have been used in psycholinguistic studies of sentence processing because they cause considerable difficulty in comprehension. According to Tabor, Galantucci, and Richardson (2004), the main problem with these sentences is that they contain a local coherence – the sequence, “the player tossed a Frisbee” is a locally coherent utterance, within which the player is the agent, tossed is the action, and the Frisbee is the patient. The problem is that this locally coherent unit is incompatible with the global meaning of the sentence, in which the player is not the agent of tossing, but the object of being smiled at. Psycholinguistic studies have used sentences such as this to gain insight about the mechanisms that support sentence comprehension (e.g. Levy et al., 2009), but it is readily acknowledged that these sentences are “fairly obscure” (Tabor et al., 2004, p. 364). Our findings here raise the question of whether there are similar constraints on production, which would explain why these sentences are so rare. For example, one possibility is that instances of local coherence also seem like errors to the producer, who detects the local coherence during production (perhaps via monitoring) and avoids producing the utterance in that form. One way to test this hypothesis might be to elicit descriptions of such scenes but manipulate whether the critical verb uses the same form for its past tense and past participle (c.f. tossed/tossed vs. threw/thrown). If producers are sensitive to this local coherence, they should be more likely to produce the full relative clause for verbs like toss (“. . .at the player who was tossed the Frisbee”) than for verbs like throw (“. . .at the player who was thrown the Frisbee”). For now, we hypothesize that the pressure to avoid unmarked SOV for reversible events is universal, but that other factors – including communicative modality along with additional constraints on comprehension and acquisition – may influence the form of the solution. We acknowledge that the noisy-channel hypothesis also offers an account of why these sentences would be rare in production and difficult in comprehension.

The third and final logical possibility is that correspondences between sign and speech are due to the same mechanism. On the one hand, the role conflict hypothesis seems to depend on the unique ways in which physical bodily actions are literally embodied in gestural communication. Sequences of spoken words may not encounter quite the same conflict of roles when a word denoting a human object is followed immediately by an action word. On the other hand, it has been argued that even spoken language production and comprehension entail some degree of perspective-taking, and that communicative behavior is influenced by the relative ease or difficulty with which a language user can adopt the perspective of various elements in an utterance. MacWhinney (1977) argues that active construction of perspective is a natural and automatic aspect of language use in both production and comprehension, and that speakers have predictable preferences for adopting some perspectives over others.

> "It is hypothesized that the speaker-listener actively involves himself with a sentence by 'getting inside it'. Speakers tend to choose the perspective which is most compatible with the perspective which they assume in their own motoric, causal, social, and positional interactions with the world." (p. 152)

A natural implication of this view is that human beings should find it easier to adopt the perspective of other humans. He further suggests that agents are preferred relative to recipients as starting points, and that this tendency is observable in children as young as 3 years old. If indeed this view is accurate, then something like role conflict in spoken language becomes much more plausible than it might first appear.

5.4. Pantomime and sign language

Characterizing the pantomime behavior of naïve non-signers also provides useful insight into the cognitive foundations of emerging systems of manual communication (i.e. homesign and young sign languages). As noted earlier, Meir et al. (2007) reported a lexicalization pattern that was common across three sign languages of varying age, which they call "body as subject". In this pattern, the signer's own body (as distinct from the signer's hands) represents the category of lexical subject. This often corresponds to the semantic category of agent (as in the present experiments), but other thematic roles are also possible, including patient, experiencer, undergoer, and others. However, in each case the signer's body represents the highest-ranking thematic role in its clause, which (together with other factors) is argued to earn subject status. Meir et al. (2007) convincingly demonstrate that this lexicalization pattern is part of the grammar of these sign languages, and that it is one of the earliest syntactic patterns to emerge. They find sign languages that use body-as-subject and lack other forms of verb agreement, but do not find sign languages that use other forms of verb agreement but lack body-as-subject. However, the source of this pattern has remained unidentified. Is it specified in universal grammar? Does it emerge gradually through trial-and-error experimentation on the part of signers? Or is it present so early because it is a part of more domain-general cognition, rather than being specific to language?

Our results from elicited pantomime illuminate the source of this pattern by demonstrating that a very similar phenomenon (body-as-agent) appears when naïve participants describe events in pantomime. That is, when they produce action gestures, participants' own bodies take on the most prominent role in the event: the human agent. This suggests that the roots of the body-as-subject pattern lie in aspects of cognition that are common across deaf and hearing individuals, both signers and non-signers, namely the body as the origin of action. When a gestural system undergoes grammaticalization, the emerging syntax capitalizes on regularities that are already present in non-linguistic (or pre-linguistic) gesture, such that body-as-agent in pantomime becomes incorporated into a new sign language grammar as body-as-subject before other types of verb agreement evolve. Furthermore, the role conflict hypothesis presented here strongly suggests that body-as-agent has consequences for constituent order in pantomime. This then leads to novel predictions about the impact of body-as-subject on constituent order in emerging sign languages. (For a more thorough discussion of the relationship between elicited pantomime and emerging sign languages, see Hall, in preparation.)

6. Conclusions

We began by asking whether cognition tends to favor some constituent orders over others. The answer appears to be yes, and the semantic properties of the event are among the factors that determine which order is favored. By asking participants to describe reversible and non-reversible events in pantomime, we identified a cognitive constraint against the conjunction of a human patient followed by an action gesture. The parallels between how this constraint is satisfied by our participants and by natural languages suggest that this cognitive pressure is active in shaping the structure of natural languages, and that it is operative during production. The extent to which these findings apply across both signed and spoken language modalities remains a rich area for future research.

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Appendix

Appendix A

Agent	Action	Patient	Reversibility
Boy	Kiss	Ball	Non-reversible
Woman	Kiss	Ball	Non-reversible
Woman	Kiss	Bike	Non-reversible
Woman	Kiss	Box	Non-reversible
Boy	Kiss	Box	Non-reversible
Boy	Kiss	Car	Non-reversible
Man	Kiss	Car	Non-reversible
Woman	Kiss	Cat	Non-reversible
Boy	Kiss	Cat	Non-reversible
Man	Kiss	Dog	Non-reversible
Girl	Kiss	Trike	Non-reversible
Man	Lift	Ball	Non-reversible
Girl	Lift	Ball	Non-reversible
Woman	Lift	Bike	Non-reversible

Agent	Action	Patient	Reversibility
Boy	Lift	Bike	Non-reversible
Woman	Lift	Box	Non-reversible
Girl	Lift	Box	Non-reversible
Girl	Lift	Car	Non-reversible
Boy	Lift	Cat	Non-reversible
Woman	Lift	Cat	Non-reversible
Woman	Lift	Dog	Non-reversible
Woman	Pet	Ball	Non-reversible
Boy	Pet	Ball	Non-reversible
Woman	Pet	Bike	Non-reversible
Boy	Pet	Bike	Non-reversible
Woman	Pet	Box	Non-reversible
Girl	Pet	Box	Non-reversible
Boy	Pet	Car	Non-reversible
Man	Pet	Car	Non-reversible
Woman	Pet	Cat	Non-reversible
Boy	Pet	Cat	Non-reversible
Boy	Pet	Dog	Non-reversible
Man	Pet	Dog	Non-reversible
Boy	Push	Ball	Non-reversible
Man	Push	Ball	Non-reversible
Woman	Push	Bike	Non-reversible
Man	Push	Box	Non-reversible
Boy	Push	Box	Non-reversible
Man	Push	Car	Non-reversible
Boy	Push	Car	Non-reversible
Boy	Push	Cat	Non-reversible
Woman	Push	Cat	Non-reversible
Man	Push	Dog	Non-reversible
Boy	Push	Dog	Non-reversible
Girl	Push	Trike	Non-reversible
Woman	Kiss	Boy	Reversible
Boy	Kiss	Girl	Reversible
Woman	Kiss	Man	Reversible
Boy	Kiss	Woman	Reversible
Woman	Lift	Boy	Reversible
Boy	Lift	Girl	Reversible
Man	Lift	Woman	Reversible
Girl	Lift	Woman	Reversible
Woman	Pet	Boy	Reversible
Boy	Pet	Girl	Reversible
Man	Pet	Woman	Reversible

Agent	Action	Patient	Reversibility
Boy	Pet	Woman	Reversible
Girl	Push	Boy	Reversible
Woman	Push	Girl	Reversible
Woman	Push	Man	Reversible
Boy	Push	Woman	Reversible

References

Aissen J. Differential object marking: Iconicity vs. economy. Natural Language and Linguistic Theory. 2003; 21(3):435–483.

Aronoff M, Meir I, Padden C, Sandler W. The roots of linguistic organization in a new language. Interaction Studies. 2008; 9(1):131–150.

Bakker, P. Pidgins versus creoles and pidgincreoles.. In: Kouwenberg, S.; Singler, JV., editors. The handbook of pidgin and Creole studies. Wiley-Blackwell; Walden, MA: 2008. p. 130-157.

Bossong, G. Differential object marking in Romance and beyond.. In: Wanner, D.; Kibbee, DA., editors. New analyses in romance linguistics. John Benjamins; Philadelphia: 1991. p. 143-170.

Cohen JD, MacWhinney B, Flatt M, Provost J. PsyScope: A new graphic interactive environment for designing psychology experiments. Behavioral research methods, instruments, and computers. 1993; 25:257–271.

Dryer, MS. Order of subject, object, and verb.. In: Haspelmath, M.; Dryer, MS.; Gil, D.; Comrie, B., editors. The World Atlas of Language Structures Online. Max Planck Digital Library; Munich: 2008. <http://wals.info>

Ferreira VS. Ambiguity, accessibility, and a division of labor for communicative success. Psychology of Learning and Motivation. 2008; 49:209–246.

Fischer, S. Influences on word order change in American Sign Language.. In: Li, CN., editor. Word order and word order change. University of Texas Press; Austin, TX: 1975. p. 3-25.

Gell-Mann M, Ruhlen M. The origin and evolution of word order. Proceedings of the National Academy of Sciences. 2011; 108:17290–17295.

Gibson, E.; Piantadosi, ST.; Brink, K.; Bergen, L.; Lim, E.; Saxe, R. A noisy-channel account of crosslinguistic word order variation.. Psychological Science. 2013. http://dx.doi.org/10.1177/0956797612463705

Givón T. On understanding grammar. New York: Academic Press. 1979

Goldin-Meadow, S. The resilience of language: What gesture creation in deaf children can tell us about how all children learn language. Psychology Press; New York: 2003.

Goldin-Meadow S, Feldman H. The development of language-like communication without a language model. Science. 1977; 197:401–403. [PubMed: 877567]

Goldin-Meadow S, Mylander C. Gestural communication in deaf children: Noneffect of parental input on language development. Science. 1983; 221:372–374. [PubMed: 6867713]

Goldin-Meadow S, Mylander C. Spontaneous sign systems created by deaf children in two cultures. Nature. 1998; 391:279–281. [PubMed: 9440690]

Goldin-Meadow, S.; Özyürek, A.; Sancar, B.; Mylander, C. Making language around the globe: A crosslinguistic study of homesign in the United States, China, and Turkey.. In: Guo, J.; Lieven, E.; Budwig, N.; Ervin-Tripp, S., editors. Crosslinguistic approaches to the psychology of language: Research in the tradition of Dan Isaac Slobin. Psychology Press; New York: 2008. p. 27-39.

Goldin-Meadow S, So WC, Özyürek A, Mylander C. The natural order of events: How speakers of different languages represent events nonverbally. Proceedings of the National Academy of Sciences. 2008; 105:9163–9168.

Greenberg, JH. Some universals of grammar with particular reference to the order of meaningful elements.. In: Greenberg, JH., editor. Universals of language: Report of a conference held at Dobb's Ferry, NY. MIT Press; Cambridge: Apr 13–15. 1966 1961 p. 73-113.

Hall ML. Exploring regularities in emerging sign systems with experimentally-elicited pantomime. (in preparation).

Hall, ML.; Ferreira, VS.; Mayberry, RI. Producers SOV use.. Perceivers like SVO. Poster presented at the annual meeting of the Psychonomic Society; Seattle, WA. Nov. 2011

Haviland, JB. Nouns, verbs, and constituents in an emerging 'Tzotzil' sign language.. In: Gutiérrez-Bravo, R.; Mikkelsen, L.; Potsdam, E., editors. Representing language: Essays in honor of Judith Aissen. Linguistics Research Center; Santa Cruz, CA: 2011. p. 157-171.

Hawkins, J. Word order universals. Academic Press; New York: 1983.

Langus A, Nespor M. Cognitive systems struggling for word order. Cognitive Psychology. 2010:291–318. [PubMed: 20189553]

Levy R. A noisy-channel model of rational human sentence comprehension under uncertain input. Proceedings of the 13th conference on empirical methods in natural language processing. 2008:234–243.

Levy R, Bicknell K, Slattery T, Rayner K. Eye movement evidence that readers maintain and act on uncertainty about past linguistic input. Proceedings of the National Academy of Sciences. 2009; 106:21086–21090.

Li, CN. Mechanisms of syntactic change. University of Texas Press; Austin: 1977.

Li CN, Thompson SA. An explanation of word order change SVO → SOV. Foundations of Language. 1974; 12:201–214.

Kouwenberg S. From OV to VO: Linguistic negotiation in the development of Berbice Dutch Creole. Lingua. 1992; 88:263–299.

MacWhinney B. Starting points. Language. 1977; 53:152–168.

Mayberry RI, Lock E, Kazmi H. Linguistic ability and early language exposure. Nature. 2002; 417:38. [PubMed: 11986658]

McWhorter J. The world's simplest grammars are creole grammars. Linguistic Typology. 2001; 5:125–166.

Meir, I.; Lifshitz, A.; Ilkbasaran, D.; Padden, CA. The interaction of animacy and word order in human languages: A study of strategies in a novel communication task.. Paper presented at the 8th international conference on the evolution of language; Utrecht, Germany. Apr. 2010

Meir I, Padden CA, Aronoff M, Sandler W. Body as subject. Journal of Linguistics. 2007; 43:531–563. [PubMed: 23066169]

Newmeyer, FJ. On the reconstruction of "proto-world" word order.. In: Knight, C.; Studdardt-Kennedy, M.; Hurford, JR., editors. The evolutionary emergence of language. Cambridge University Press; New York: 2000. p. 372-388.

Sandler W, Meir I, Padden C, Aronoff M. The emergence of grammar: Systematic structure in a new language. Proceedings of the National Academy of Sciences. 2005; 102:2661–2665.

Senghas, A.; Coppola, M.; Newport, EL.; Supalla, T. Argument structure in nicaraguan sign language: The emergence of grammatical devices.. In: Hughes, E.; Hughes, M.; Greenhill, A., editors. Proceedings of the Boston university conference on language development. Vol. 21. Cascadilla Press; Boston: 1997. p. 550-561.

Sinnemäki K. Word order in zero-marking languages. Studies in Language. 2010; 34:869–912.

Sun C, Givón T. On the so-called SOV word order in Mandarin Chinese: A quantified text study and its implications. Language. 1985; 61:329–351.

Tabor W, Galantucci B, Richardson D. Effects of merely local syntactic coherence on sentence processing. Journal of Memory and Language. 2004; 50:355–370.

Tomlin, RS. Basic word order: Functional principles. Croom Helm; London: 1986.

Vennemann, T. Explanation in syntax.. In: Kimball, JP., editor. Syntax and semantics. Vol. 2. Seminar Press; New York: 1973. p. 1-50.

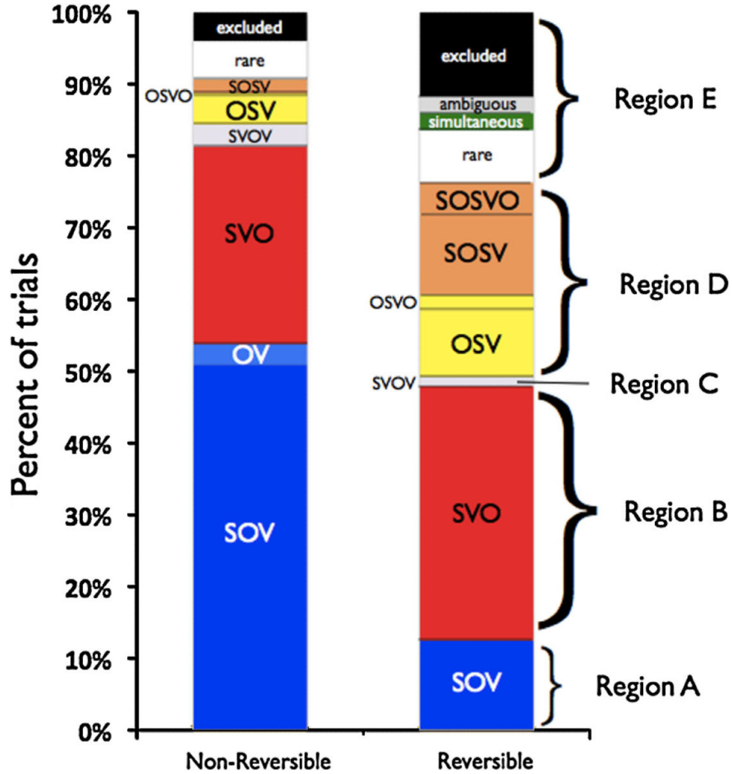

Fig. 1.

Constituent orders across all participants, for non-reversible (left) and reversible (right) trials. For reversible events, Region A shows orders that are inconsistent with the confusability, noisy-channel, and role conflict hypothesis. Region B shows orders that are consistent with all hypotheses. Region C shows orders that are uniquely consistent with confusability and noisy channel accounts. Region D shows orders that are uniquely consistent with role conflict. Region E shows orders that are uninformative with respect to these hypotheses. Rare orders are defined as those that account for less than 2% of trials for both non-reversible and reversible events.

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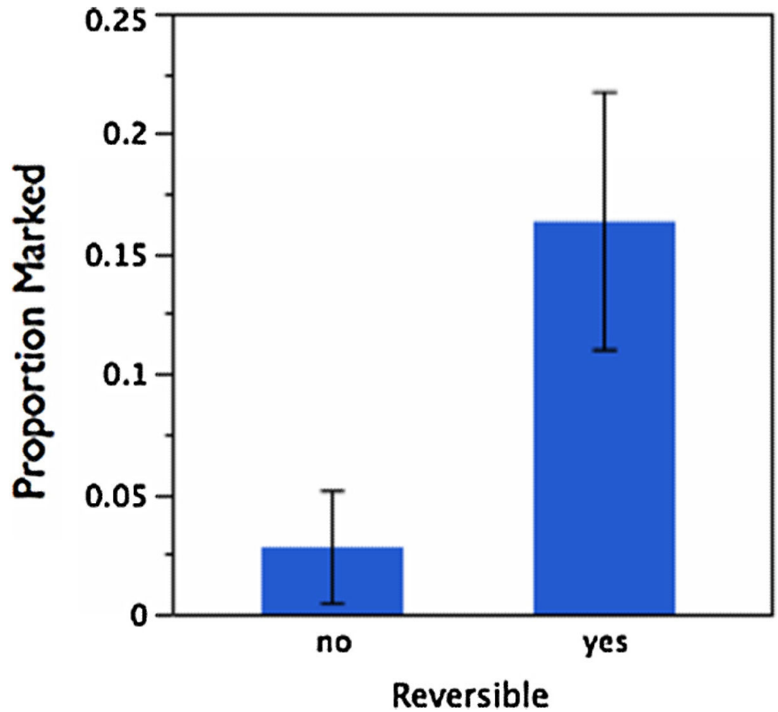

Fig. 2.
Proportion of trials containing gestures that resembled case markers, for non-reversible and reversible trials.

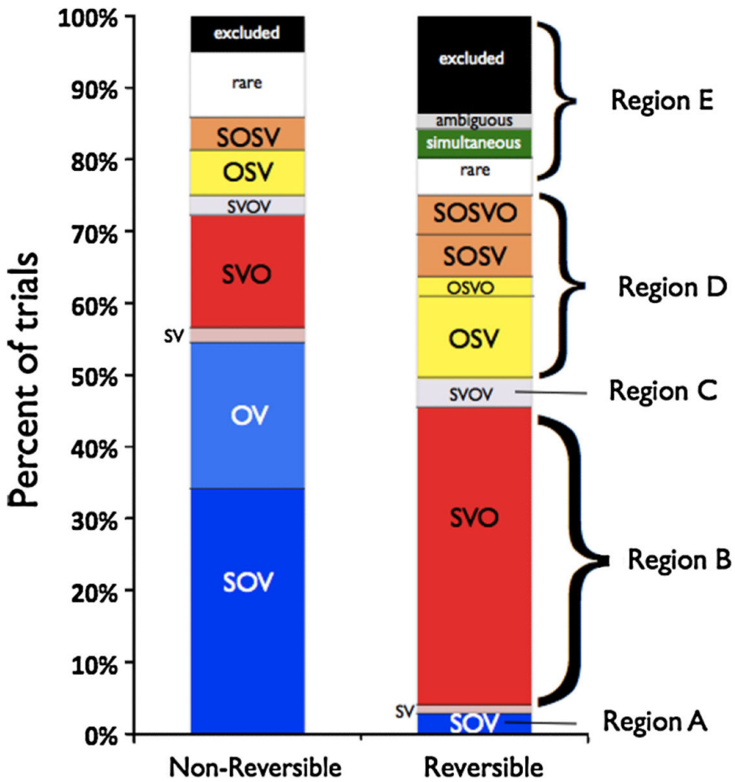

Fig. 3.

Constituent orders across all participants, for non-reversible (left) and reversible (right) trials. Regions A–E are defined as in Fig. 1.

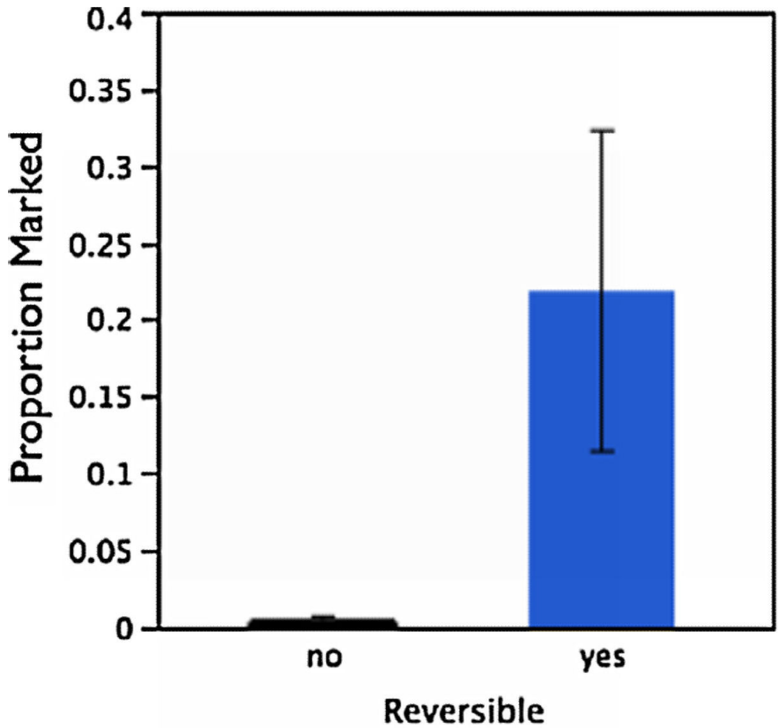

Fig. 4.

Proportion of trials containing gestures that resembled case markers, for non-reversible and reversible trials.

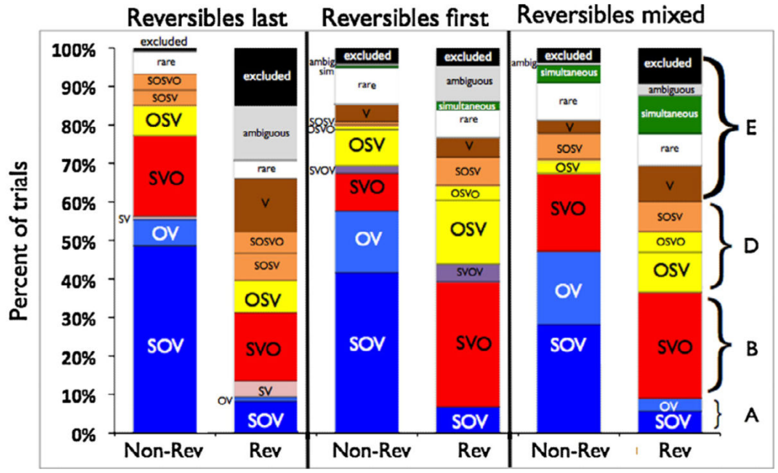

Fig. 5.
Constituent orders across all participants in each condition, for non-reversible and reversible trials. Regions A–E are defined as in Fig. 1.

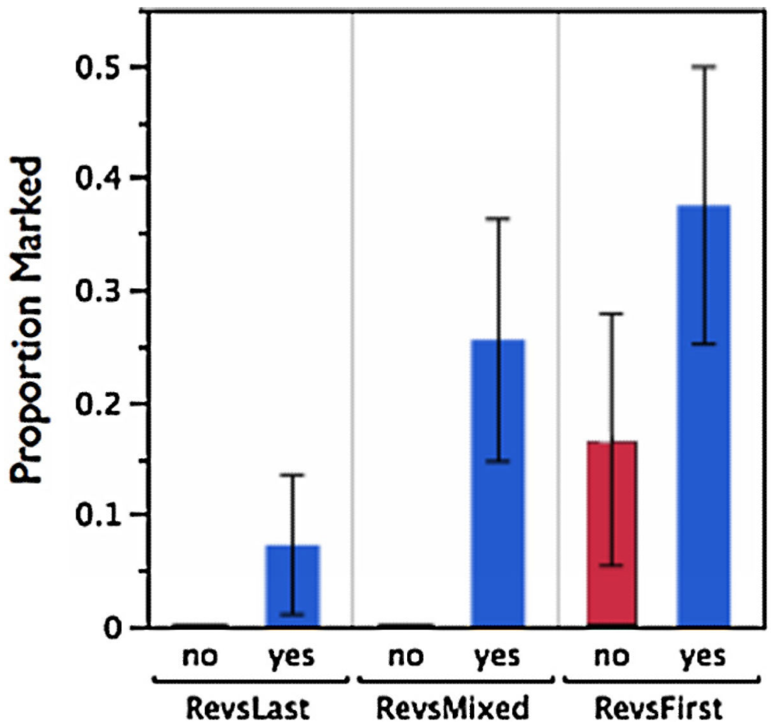

Fig. 6.

Proportion of trials containing gestures that resembled case markers, for non-reversible and reversible trials, by condition.