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Learners sacrifice robust communication as a result of a social bias

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Abstract

Languages are subject to many competing pressures, which originate in individual-level learning and communication biases and in social biases reflecting community-level dynamics. Recent work suggests that certain aspects of language structure, such as the cross-linguistic trade-off between case and constituent-order flexibility, originate in learners' biases for efficient communication: Learners drop redundant case but retain informative case in production. Social biases can lead to retention of redundant case, resulting in systems that require more effort to produce. It is not clear, however, whether social biases can influence the use of informative cues. We tested this by exposing participants to a language with uninformative constituent order and two dialects, only one of which employed case. We manipulated the presence of social biases for and against the case dialect. Learners biased towards the no-case dialect dropped informative case without compensating for the resulting message uncertainty. Case was retained in all other conditions.

Keywords: language change; learning biases; social biases; miniature artificial language; language acquisition; language universals; language evolution

An important function of language is to convey reliable information about events. For this to succeed, utterances must reduce uncertainty about the thematic roles of those involved in the events (i.e., who is doing what to whom). In a sentence like "Congress impeached the President", English constituent order leaves little uncertainty as to who impeached whom. Other languages might achieve the same goal by different means. Classical Latin, for example, allowed much more flexibility in constituent order while using case markers (morphological elements on nouns and pronouns that indicate their grammatical role) to distinguish thematic roles. Other mechanisms employed in various languages include agreement (e.g., marking subject and object on the verb, as in Nahuatl), prosody, and pragmatics. To some extent these different mechanisms may coexist in the same language, but no known language makes use of all cues to the same degree.

For instance, it has long been observed that there exists a trade-off such that languages with more fixed constituent order tend to exhibit less case marking, and vice versa (Sapir, 1921; Koptenig, Meyer, Wolfer, & Mueller-Spitzer, 2017). This cross-linguistic trade-off has been argued to derive from pressures to balance uncertainty about the intended meaning against production effort (Fedzechkina, Jaeger, & Newport, 2012; Kurumada & Jaeger, 2015; Jäger, 2007). Fedzechkina and Jaeger (2020) provided direct experimental evidence to

support this view. They trained participants on miniature artificial languages with optional case marking and manipulated both the amount of constituent-order flexibility and the effort required to produce case markers. They found that the cross-linguistic trade-off between case and constituent-order flexibility (i.e., using more case in a flexible-order language compared with a fixed-order language) only emerged when case markers required additional effort to produce compared with non-case-marked nouns, thus supporting the idea that this trade-off stems from a bias to balance uncertainty about the intended meaning against production effort.

However, languages are subject not only to the kind of individual-level learning and communicative pressures described so far; they are also subject to social biases originating in community-level dynamics. It is very common for certain linguistic variants to acquire positive or negative social associations unrelated to any intrinsic communicative or processing quality of the variant itself (Garrett, 2010). So-called h-dropping (e.g., *'ouse* for *house*), for example, typically has low social prestige in modern varieties of English, while certain varieties in which /t/ is "dropped" except before vowels (e.g., /ka/ for *car* in Received Pronunciation) are among the most prestigious. This kind of social bias can interact with other pressures, such as those invoked in the trade-off between case and constituent order, modulating their influence. For example, the continued existence of English *whom* is likely to be due to its social prestige rather than any genuine role in reducing referential uncertainty (Lasnik & Sobin, 2000).

Roberts and Fedzechkina (2018) conducted an experiment to investigate how these different pressures interact. Participants in diffusion chains learned a miniature "alien" language with two dialects. For the first generation of participants in each chain, both dialects had 100% consistent constituent order. The dialects differed with regard to case marking: One dialect consistently marked all objects, while the other dialect consistently left all objects zero-marked. Thus, overall, the language had fixed constituent order and optional case marking that was redundant in the sense that it did not convey information about the intended meaning above and beyond constituent order alone. After training, participants produced sentences to describe previously unseen simple transitive scenes. These sentences formed the basis of the input for the next generation of learners. Social biases were ma-

nipulated by varying the text of the instructions, with four between-participant conditions in which participants were (a) biased towards speakers of the case-marking dialect, (b) biased towards speakers of the no-case-marking dialect, (c) biased *against* speakers of the case-marking dialect, or (d) not given any social bias at all. Roberts and Fedzechkina (2018) found that the redundant case marker disappeared rapidly in all conditions but one: When learners were biased in favor of the case-marking aliens, they were more likely to maintain case marking in the language. In this condition the case marker also declined in use, but more slowly, and it did not disappear completely (unlike in all other conditions). Importantly, the results of the condition with a bias *against* the case-using aliens (which were the same as for the no-bias condition) confirmed that the effect of the social bias was not simply to direct greater attention to the aliens in question.

In Roberts and Fedzechkina’s (2018) study, consistent constituent order meant that case markers were unnecessary for reducing message uncertainty. They contributed nothing to robust message transmission and cost an additional small amount of effort to produce, so it is not surprising that they disappeared in most conditions of the experiment. A social bias in favor of the case dialect’s users, however, created a social niche for case markers: They acquired an additional social function that partly offset the production effort cost of retaining them (cf. Lasnik & Sobin, 2000). In this light it is important to ask what role a social bias could play in the loss or retention of *informative* case (i.e., in a language where constituent order is uninformative). Could a social bias in favor of a no-case dialect lead learners to drop case? This scenario is considerably less straightforward than the question Roberts and Fedzechkina (2018) investigated. In line with their results, we might expect case to be lost, but this would lead to considerable uncertainty about the intended message in the resulting linguistic system. Thus, it is possible, on the one hand, that learners might prioritize robust message transmission and retain case in spite of the social bias against it. On the other hand, it is possible that learners might prioritize the social bias against case and sacrifice robust message transmission, producing linguistic systems with a high degree of uncertainty. In the latter instance, learners might concomitantly change other aspects of the grammar to compensate for the increased uncertainty.

We investigated this experimentally by exposing participants to a language with both flexible constituent order and dialectal variation in whether or not there was case marking. Like Roberts and Fedzechkina (2018) we manipulated social biases as a between-participant variable, biasing different groups of participants either towards the case-marking dialect, to the no-case dialect, or to neither. After exposure to the language participants produced sentences in response to stimuli. Our primary research question concerned whether participants’ use of the *informative* case marker in production was affected by the social bias. We further investigated whether participants introduced other changes into the lin-

guistic systems they produced to modulate message uncertainty.

The experiment

Participants

Monolingual native English speakers with no known language disorders (based on self-reports) were recruited using the Prolific Academic platform. The experiment was administered using FindingFive, a platform for online study administration (Finding Five Corporation, 2019). Participants received \$7 for their participation in the study which lasted approximately 50 min. Following prior work (Fedzechkina, Newport, & Jaeger, 2017; Fedzechkina & Jaeger, 2020), participant recruitment continued until the number of participants who had successfully learned the miniature language reached 20 in each condition. Successful learning was defined exactly as by Fedzechkina et al. (2017). The final sample submitted for analysis included 60 participants (out of 96 participants who completed the experiment; see Scoring section below).

Miniature input language

Participants were instructed that they would be learning an “alien” language by watching short videos and hearing sentences describing them produced by an alien informant. The language contained four nouns that corresponded to humanoid referents (CHEF, MOUNTIE, REFEREE, BANDIT), two transitive verbs (KICK and HUG), and a case suffix “-dak” that (if present) attached to the object of the verb. The language was presented both auditorily and in writing; participants produced language by typing.



Figure 1: Examples of sentence exposure (left) and sentence production (right) trials. Pictures represent still images of the videos participants saw. The alien informant was present in each sentence-exposure video but absent during sentence-production trials.

Participants were explicitly informed that the language had two dialects, each of which was spoken by a different color of alien (blue or orange). Both dialects had flexible constituent order with subject-object-verb (SOV) and object-subject-verb (OSV) orders occurring equally frequently. The dialects differed in whether or not there was case marking: In the case dialect, the suffix “-dak” was always present on the object-noun; in the no-case dialect, no noun was case-marked. Thus,

the language overall had 50% SOV constituent order and 50% case marking (with case marking, but not constituent order, socially conditioned). An alien informant (blue or orange) was shown with every sentence in sentence-exposure and comprehension trials (see Procedure section) to indicate the dialect spoken on each trial, but was absent in sentence-production test trials, in which participants produced their own sentences (Fig. 1).

Bias conditions

Participants were randomly assigned to one of three bias conditions in which, following Roberts and Fedzechkina (2018), the text of the instructions was manipulated to encourage participants to feel positive about and to impress particular species of alien as potential trading partners.¹ In the *No-bias* condition, participants were told that there were two species of aliens who speak slightly different dialects. Participants were encouraged to feel positive towards the aliens overall, but not towards either species of alien in particular. In the other two conditions, participants were encouraged to feel positive towards one group of aliens relative to the other – either the speakers of the case dialect in the *Bias-for-case* condition or the speakers of the no case dialect in the *Bias-for-no-case* condition. In all instructions alien species were identified to participants by their color rather than by the type of dialect they used.

Procedure

At the beginning of the experiment, participants were informed that they would be learning a novel “alien” language by watching short videos and hearing descriptions of them in the novel language. No further instructions about the structure of the language were provided.

The study began with **noun exposure**. Learners were familiarized with the referents used in the study by viewing a picture of each humanoid referent, presented in isolation and accompanied (both visually and auditorily) by a label in the alien language. After noun exposure, the **noun comprehension** stage began, in which learners were presented with pictures of four humanoid referents accompanied with a label corresponding to one of them. Learners were instructed to click on the correct picture. Noun learning concluded with a **noun production** test, in which learners were asked to type a label for each humanoid referent presented in isolation. To facilitate vocabulary learning, which was necessary for the experiment to succeed but not otherwise of experimental interest, feedback was provided on every trial for noun comprehension and production tests. Learners completed two sets of noun exposure, comprehension, and test blocks before moving to the next stage of the experiment.

¹Roberts and Fedzechkina (2018) included a condition in which participants were encouraged to feel *negative* about a particular species of alien; since this condition served chiefly as a manipulation check to ensure that any bias effect was not simply due to increased attention towards the specified aliens (which was confirmed), we did not consider it necessary to repeat such a manipulation check here.

During the following **sentence exposure** trials, learners watched short videos (four blocks of 16 trials each) depicting simple transitive events (e.g., the chef hugging the moun-tie) accompanied by corresponding sentences in the alien language. Every video included a blue or an orange alien as a cue to the dialect used by the informant (Fig. 1). Throughout the study, learners could replay the video and sound/text as many times as they wished. Sentence exposure was followed by **sentence comprehension** trials (16 in total) in each of which learners heard a sentence in the language and were shown two videos depicting the same referents and action, but with the thematic roles reversed (i.e., with the agent in one video taking the patient role in the other). Participants were asked to click on the video that matched the sentence. As in sentence exposure trials, each video included a colored alien informant as a cue to dialect. No feedback was provided on sentence comprehension trials. After completing sentence comprehension, learners began **sentence production** (16 trials). In these trials, they watched previously unseen videos depicting familiar characters and actions and described them in the novel language. Participants were given an auditory prompt to the verb to make their task easier. Sentence production videos contained no image of an alien informant, thus allowing participants to align their sentences with whatever dialect they wished. No feedback was provided on sentence production trials.

After completing sentence production, participants completed another set of four sentence exposure blocks, one sentence comprehension block, and one sentence production block.

Scoring

During the study, we recorded accuracy on comprehension and production trials, as well as participants’ case and constituent order preferences in sentence production. In the sentence comprehension trials, we assessed whether participants clicked on the correct video on case-marked (i.e., unambiguous) trials only. Since constituent order was uninformative in our experiment, this measure indicated how well learners had acquired the meaning of case marking. Following (Fedzechkina et al., 2017), participants who failed to reach 70% accuracy on the final comprehension test were removed from the analysis. This included seven participants in the bias-for-case condition, nine participants in the bias-for-no-case condition, and 17 participants in the no-bias condition.

All noun and sentence production trials were automatically scored for accuracy using a custom Python script. A noun or verb was considered lexically correct if it fell within a Levenshtein distance of two from the target label (i.e., we allowed at most two character insertions, deletions, or substitutions in a word). For example, ‘togla’ was still considered a correct label for ‘dokla’, but ‘togli’ was not. For each sentence produced by participants, we recorded which constituent order was used, the presence and position of case marking as well as the presence of lexical mistakes (using the wrong name for a referent or an action) and grammatical mistakes (i.e., a

constituent order other than SOV or OSV or a case marker used on the wrong constituent). If the name of only one referent was incorrect and it was still possible to determine sentence constituent order, productions were scored as overall correct but containing a lexical error. Such productions were included in the analyses below. Sentences containing more than one lexical mistake were removed from the analysis as constituent order was impossible to determine for these sentences. A sentence containing at least one grammatical (case or constituent order) mistake was scored as grammatically incorrect and excluded from all analyses (less than 8% of the data across both sentence production blocks). Additionally, three participants were excluded from the analysis for producing less than 50% parsable utterances on the final sentence production test.

Results

Accuracy of acquisition

For participants included in the analysis, vocabulary test performance was at ceiling on the final vocabulary test (95% correct). Similarly, the number of lexical mistakes during sentence production was around 1% on the final sentence production test. The number of grammatical mistakes made by the learners was below 3% on the final sentence production block. This performance suggests that despite the difficulty of the task, it was feasible for our participants.

Case use in production

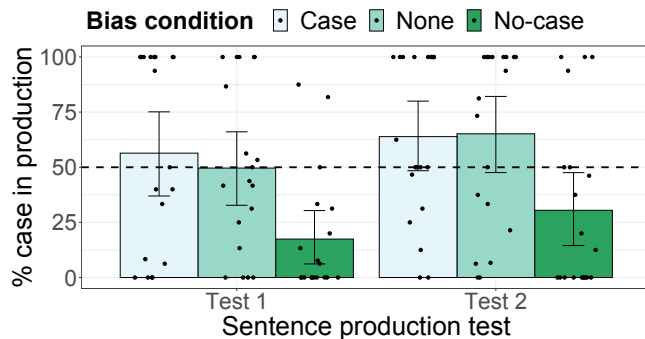


Figure 2: Case use in production by bias condition. The dashed line represents the input proportion (same across bias conditions). The dots represent individual participant means. The error bars represent bootstrapped 95% confidence intervals.

We now turn to the main question of our study – whether learners introduced changes into the distribution of an informative cue (case marking) as a result of a social bias. To address this question, we used mixed effects logistic regression to predict case-marker use from the bias condition (Sliding difference coded: no-bias vs. bias-for-case; bias-for-no-case vs. no-bias condition), sentence production block (sum coded, 2 vs. 1), and their interactions. The model contained

maximal converging random effects structure (random intercepts for participant and item, and by-participant random slope for production test block).

There was a main effect of block on case use ($\beta = 0.86$, $z = 2.9$, $p = 0.003$) – across all bias conditions, learners used more case marking in the second sentence production block compared with the first one. This is consistent with prior work (Fedzechkina & Jaeger, 2020; Fedzechkina et al., 2017) and suggests that case-marker use increased as participants became more proficient in the language. Learners’ case use did not differ between the No-bias and the Bias-for-case conditions ($\beta = -0.3$, $z = -0.61$, $p = 0.54$; Fig. 2), suggesting that a social bias to feel positively inclined towards the speakers of the case dialect was not strong enough to force learners to increase case use beyond the baseline (i.e., beyond the No-bias condition). However, learners used significantly less case in the Bias-for-no-case condition compared with the two other conditions ($\beta = -1.65$, $z = -3.12$, $p = 0.002$) suggesting that a social bias to feel positively inclined towards speakers of the no-case dialect lead learners to use less case in their own productions. There were no other significant effects in the model (smallest $p > 0.4$).

To further understand how learners used case marking in the three bias conditions, we compared learners’ case use to the input on the second sentence production test. We used mixed-effects logistic regression to predict the amount of case use from the bias condition and the maximal random effects structure (random intercepts by participant and by item). We employed three different parameterizations of the same regression, each differing only in terms of which of the three bias conditions was chosen as the reference level for treatment coding. In these regressions, the intercept captures whether case use in the bias condition coded as reference level differs significantly from the input. This analysis revealed that learners in the Bias-for-case matched the input (63% case; not significantly different from the input, $\beta = 2.7$, $z = 1.92$, $p = 0.054$); learners in the No-bias conditions produced significantly more case marking than the input (65% case use in the No-bias, significantly higher than the input, $\beta = 2.765$, $z = 1.9$, $p = 0.048$). Learners in the Bias-for-no-case condition, on the other hand, produced significantly less case marking than the input (30% case, significantly lower than the input, $\beta = -3.25$, $z = -2.22$, $p = 0.026$).

Thus, learners in our study introduced changes into the distribution of case marking beyond the baseline (i.e., the distribution in the No-bias condition) only if the social bias was in favor of the speakers of the no-case dialect. This is somewhat surprising as constituent order was uninformative about sentence meaning (SOV and OSV orders occurred equally frequently in the input) and case marking, when present, provided important information about sentence meaning. Dropping case marking in our language reduced production effort (as it would involve typing four fewer characters) but potentially increased message uncertainty. However, it is possible that, while dropping case markers, participants also re-

structured the system in some other way to reduce uncertainty about the intended meaning (e.g., by fixing constituent order). We turn to this question in the next section.

Uncertainty about the intended meaning

Given the grammar of our language, there were several ways in which learners could reduce uncertainty about the intended message without increasing the proportion of case marking in their production – they could increase the use of one constituent order variant (either SOV or OSV) above the input proportion, condition case-marker use on a particular constituent order variant, or settle on some combination of these two strategies.

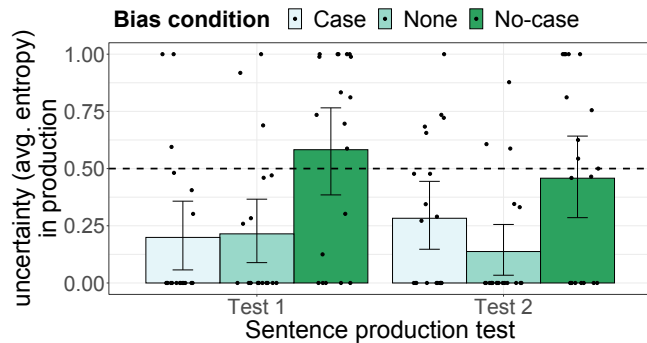


Figure 3: Uncertainty about the intended meaning in production by bias condition. The dashed line represents the input (same across bias conditions). The dots represent individual participant means. The error bars represent bootstrapped 95% confidence intervals.

Learners in our study did not receive any instruction on what structures to use in production, and related work using this paradigm has found a great deal of variation in the strategies learners adopt (Fedzechkina et al., 2017). Thus, we expected similar variation in between-learner strategies in our study. To capture the amount of meaning uncertainty in the linguistic systems produced by learners – irrespective of their adopted strategy with respect to case or constituent-order use – we calculated the conditional entropy of the sentence meaning (in terms of thematic-role assignment). Given the input grammar, minimal conditional entropy of thematic role assignment (0 bits) is achieved by all systems that have no constituent-order variation (regardless of the presence of case marking) or in systems that have consistent case marking (regardless of constituent-order variation). Maximal conditional entropy of 1 bit is achieved in a system that has two constituent orders in equal frequencies and no case marking. The remaining possible systems given our input fall somewhere in-between.

To compare the average conditional entropy of the systems produced by learners across bias conditions, we used linear regression to predict conditional entropy from bias condition (sliding difference coded), sentence production block (sum coded), and their interactions. There was a main effect of the

Bias-for-no-case condition: Learners in this condition produced linguistic systems that had significantly higher conditional entropy of thematic role assignment compared with the other bias conditions ($\beta = 0.11$, $z = 4.23$, $p = 0.00004$; Fig. 3). The No-bias condition did not significantly differ from the Bias-for-case condition ($\beta = -0.02$, $z = -0.79$, $p = 0.42$). There were no other significant effects in the model (smallest $p > 0.3$).

This analysis suggests that, as a result of the social bias, learners in the Bias-for-no-case condition dropped case without introducing other changes into the system to reduce uncertainty about the thematic role assignment, thus producing linguistic systems with high uncertainty about the intended message.

Discussion

We asked whether a social bias in favor of a particular group of speakers of a language would influence how learners of this language use an *informative* cue in production. Specifically, we presented learners with a miniature artificial language that had uninformative constituent order and (in one dialect only) informative case marking. We found that when no social bias was present (in the No-bias condition), learners retained case marking in their own productions, producing it slightly above input frequency in the language as a whole. This replicates prior work by Fedzechkina et al. (2017) and Fedzechkina and Jaeger (2020), who showed that, in the absence of other pressures, learners of a flexible constituent-order language retain case in their productions, thus balancing the production effort expended on case use against uncertainty about the intended message. Furthermore, when there was a social bias supporting case use (i.e., in the Bias-for-case condition), learners’ case use did not differ from the No-bias baseline. On the other hand, when there was a social bias against case (i.e., in the Bias-for-no-case condition), learners substantially reduced case marking in their productions relative to the input. Taken together these results suggest that production effort costs, uncertainty reduction, and social biases play an important role in language change, but these pressures interact with each other resulting in pathways for language change that are not necessarily straightforward or obvious. A social bias (coupled with a production effort cost) was sufficient to reduce case use, thereby increasing message uncertainty, but it was not sufficient to increase case use in spite of the decrease in message uncertainty that it would bring about.

These findings conceptually replicate and extend prior work by Roberts and Fedzechkina (2018), who found that, in an iterated learning study, learners exposed to a fixed-constituent-order language retained redundant case marking (i.e., case marking that required effort to produce but did not reduce message uncertainty) only in the presence of a social bias favoring it. The current study found that in response to a social bias, learners changed the distribution of an *informative* cue in their productions, which led to increased uncertainty about the intended message (i.e., to linguistic systems

in which a large proportion of utterances were globally ambiguous).

This is particularly intriguing, as the affordances of our input language and the constraints of the experimental task allowed learners to reduce uncertainty about thematic role assignment even while dropping case marking (e.g., by fixing constituent order or by conditioning case on constituent order). One might ask why the learners in our study did not make use of such strategies, instead producing linguistic systems with high message uncertainty. One clear possibility is that the pressure to reduce uncertainty was not especially strong. Participants were not directly rewarded for doing so or penalized for producing ambiguous sentences. Nor did the task involve communicating a message to an interlocutor who could provide feedback about uncertainty. This is not to say that communicative pressures were entirely absent in our experiment. Indeed, our task was designed to simulate a communicative interaction, and participants were explicitly asked to imagine they were talking to, and trying to impress, different groups of alien speakers. The fact that participants were influenced by social biases that made direct reference to those aliens suggests that we were successful in this. Nevertheless, it is a potential limitation of the study that participants neither had nor believed they had a genuine interlocutor, and it would be worth introducing one in future work. Long-standing work on dialog suggests that interlocutor feedback makes a difference to both communicative success and speaker behavior (Schober & Clark, 1989; Clark & Krych, 2004), and experimental evidence from the field of language evolution suggests that communicative interaction supports the emergence of expressive communication systems (Kirby, Tamariz, Cornish, & Smith, 2015; Garrod, Fay, Lee, Oberlander, & MacLeod, 2007). However, it should not be assumed that the presence of an interlocutor would *necessarily* lead to significant reduction of message uncertainty in the presence of a social bias that pulls learners in the opposite direction. For example, other experimental work suggests that language users do not reliably take into account interlocutors' perspectives in all circumstances (Keysar, 2007; Savitsky, Keysar, Epley, Carter, & Swanson, 2011) and can be swayed by cognitive biases away from communicatively optimal behavior (Lane, Groisman, & Ferreira, 2006). Investigating the role of interlocutor presence and feedback, in other words, constitutes a crucial next step in this paradigm.

A further possible explanation for the failure to reduce message uncertainty has to do with the nature of the grammatical structures involved. Fedzechkina et al. (2017) and Fedzechkina and Jaeger (2020) showed that native English speakers (the same population as our participants) readily introduce changes into case distributions but are more reluctant to strongly deviate from input constituent-order distributions. Given this, it may be unsurprising that our participants did not fix constituent order in a single generation. That is, it is possible that a bias to reduce message uncertainty by fixing constituent order is present in individual learners but is

so small that it can only be observed after being amplified by generational transmission (Kirby, Griffiths, & Smith, 2014). Together with interlocutor feedback, this is another element to incorporate in future work, which could be done easily by employing an iterated-learning paradigm as in Roberts and Fedzechkina's (2018) study.

The work described here constitutes a second step in a paradigm that began with that study. It clearly replicates Roberts and Fedzechkina's (2018) results, showing that communicative and learning pressures interact with social biases, potentially leading to languages that less efficiently convey information about events in the world than might otherwise be expected. But this study goes beyond that in suggesting that social pressures can actually *increase* the potential for uncertainty about the thematic roles of event participants. As discussed, however, it is possible that this effect depends in part on the strength of the communicative pressure (e.g., the presence and quality of interlocutor feedback) or that it is a relatively short-lived effect, reduced by repeated learning. It is also likely, on the other hand, that the nature of the social bias – implemented here in a very simple form – makes an important difference. The next steps in the paradigm will involve asking precisely these questions and probing further how different kinds of social, communicative, and learning bias interact in shaping the structure of languages.

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