Incrementality and efficiency shape pragmatics across languages

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To correctly interpret a message, people must attend to the context in which it was produced. Here we investigate how this process, known as pragmatic reasoning, is guided by two universal forces in human communication: incrementality and efficiency, with speakers of all languages interpreting language incrementally and making the most efficient use of the incoming information. Crucially, however, the interplay between these two forces results in speakers of different languages having different pragmatic information available at each point in processing, including inferences about speaker intentions. In particular, the position of adjectives relative to nouns (e.g., "black lamp" vs. "lamp black") makes visual context information available in reverse orders. In an eye-tracking study comparing four unrelated languages that have been understudied with regard to language processing (Catalan, Hindi, Hungarian, and Wolof), we show that speakers of languages with an adjective–noun order integrate context by first identifying properties (e.g., color, material, or size), whereas speakers of languages with a noun–adjective order integrate context by first identifying kinds (e.g., lamps or chairs). Most notably, this difference allows listeners of adjective–noun descriptions to infer the speaker's intention when using an adjective (e.g., "the black. . ." as implying "not the blue one") and anticipate the target referent, whereas listeners of noun–adjective descriptions are subject to temporary ambiguity when deriving the same interpretation. We conclude that incrementality and efficiency guide pragmatic reasoning across languages, with different word orders having different pragmatic affordances.

pragmatics | cross-linguistic variation | adjective position | visual search | interpretation processes

Language is used in context, and it is only in context that it acquires its intended meaning. Recognizing the speaker's intention is therefore part of the process of interpreting a message (1). A simple sentence such as "John is good at sports" would normally be interpreted as a positive comment in most contexts, but not in response to the question, "Is John a good student?". The process whereby listeners infer speaker intentions to interpret a message in context—broadly known as pragmatic reasoning—is universal, applying to all languages and communicative situations. Given this universal scope, pragmatic theories typically provide accounts of how context contributes to meaning, independent of the language in use. Here we show that, even though speakers of all languages interpret language in context, real-time pragmatic reasoning depends on language structure.

Language comprehension is a highly inferential process where different sources of information about the sounds, word meanings, and structure of a message are integrated with context to derive the intended interpretation (2, 3) (for review, see refs. 4 and 5). Among the contextual information that listeners may factor into this interpretation are speaker intentions. The role of speaker intentions in communication has figured prominently in pragmatic theories (1, 6), computational models (7, 8), and philosophical accounts (9, 10). Here we propose to study pragmatic reasoning from a cross-linguistic perspective to better understand how speaker intentions constrain real-time language interpretation.

Linguistic messages in oral, written, and sign languages unfold over time, placing a universal constraint on speakers and listeners. Previous studies have shown that listeners consequently interpret language incrementally—processing words as they come—and efficiently—deriving the richest possible interpretation from the speaker's choice of words (11–14). However, because most psycholinguistic studies have been conducted in English, little is known about how incrementality and efficiency affect pragmatic reasoning across languages (15, 16). We focus on a frequent form of pragmatic reasoning known as contrastive inference, which has been shown to enable English speakers to anticipate a target referent in certain visual contexts (17, 18). By adopting a cross-linguistic perspective, we aim to provide a more robust test of the effects of incrementality and efficiency on pragmatic reasoning, while investigating how speaker intentions inform real-time reference resolution across different languages.

World languages are divided into those that position adjectives before nouns, like English, and those that position them after (19). Because language is interpreted incrementally, adjective position should affect the order in which listeners integrate the visual context in their reference interpretation. Consider, for instance, a display with two lamps, one black and

Significance

Pragmatic theories account for the types of inferences that people must derive to interpret language in context (e.g., the speaker's intention in using a word), regardless of their language. Here we show that a language's word order determines how pragmatic inferences inform real-time interpretation and how this results from languages being interpreted incrementally and efficiently. In an eye-tracking study comparing four typologically unrelated languages—Catalan, Hindi, Hungarian, and Wolof—we find that, upon seeing identical displays and hearing equivalent descriptions, speakers of adjective–noun languages resolve reference earlier by inferring the intended function of adjectives. Our work shows that, while all language interpretation relies on pragmatic inference, understanding how speaker intentions inform real-time language interpretation calls for a cross-linguistic investigation.

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one blue, and a black chair (Fig. 1, *Bottom*). When speakers of an adjective–noun language interpret the description "the black lamp," incrementality predicts that they should scan the visual display guided by color and then refine their search by kind (i.e., first identifying black objects and, among those, the lamp). By contrast, when speakers of a noun–adjective language interpret the reverse description "the lamp black," they scan the visual display guided by kind and then refine their search by color (i.e., first identifying lamps and, among those, the black one).

More importantly, because language is interpreted efficiently, adjective position should also affect the pragmatic inferences underlying reference resolution. In the same situation as above (Fig. 1, *Bottom*), a speaker of an adjective–noun language like English, upon hearing "the black …," could recognize the speaker's intention to use the adjective contrastively (i.e., to distinguish between competitors; in this case, the two lamps). This would allow the listener to anticipate that the referent must be the black lamp (and not the black chair), even before the listener hears the noun. This prediction is based on the pragmatic assumption that speakers are (perhaps subconsciously) rational and cooperative (1): A reasonable speaker is more likely to use "black" to preempt an ambiguity between the two lamps than to introduce an unnecessary ambiguity between the two black objects. This kind of pragmatic reasoning is known as a contrastive inference and is highly efficient, but possible only if the adjective precedes the noun (see Fig. 1, *Bottom* for an illustration of this inference). A speaker of a noun–adjective language would be unable to apply the same reasoning upon hearing "the lamp …" and would have to wait for the adjective to identify the target referent. Crucially, adjectives are not always interpreted contrastively, since they are often used descriptively (17, 18, 20, 21). Therefore, deriving a contrastive inference relies on identifying the intended function of the adjective in the context (22, 23).

While it has long been proposed that word order patterns interact with universal processing mechanisms to yield different patterns of processing behavior (24, 25), few eye-tracking

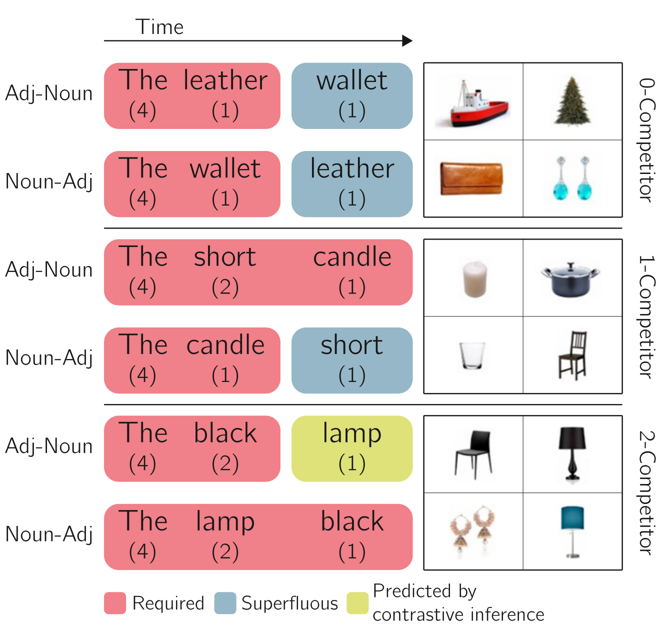

Fig. 1. Sample displays from the three conditions and adjective types. The description of the target object (presented auditorily in the experiment) is written next to each display in the two orders of interest. Numbers in parentheses indicate the number of potential referents after processing each word.

studies have investigated the effect of incrementality and efficiency in languages other than English (e.g., refs. 16, 26, and 27). In the case of reference resolution, previous studies have compared visual contexts where English speakers could derive a contrastive inference that allowed them to anticipate the noun (e.g., Fig. 1, *Bottom*) with those where processing the same description would result in a temporary ambiguity that could be resolved only when processing the noun (e.g., Fig. 1, *Middle* and refs. 17 and 18). The goal of our study was twofold: first, to investigate the effect of incrementality and efficiency in four languages that are typologically unrelated and different from English; and second, to test the prediction that the possibility to derive a contrastive inference in reference resolution (or otherwise suffer a temporary ambiguity) depends not only on the visual context, but also on the word order of the language in use.

To investigate how adjective position affects pragmatic reasoning, we used three types of adjectives—color (e.g., "black," "green"), material (e.g., "plastic," "leather"), and scalar adjectives (e.g., "large," "short")—in three types of visual displays (see Fig. 1 and *SI Appendix* for examples): a zero-competitor baseline where the target was the only object of its kind and relevant property (color, material, or scalar); a one-competitor condition where an object in the display shared the relevant property with the target (i.e., a property competitor); and a two-competitor condition where an object shared the relevant property with the target (a property competitor), and another object matched the target's kind (a kind competitor). The one- and two-competitor conditions are referred as "no contrast" and "contrast" conditions in the literature (3, 17, 18). These displays (8 in each condition by adjective combination for a total of $n = 72$) were selected as a representative set of simple situations that would capture cross-linguistic differences and not as an exhaustive set capturing all possible differences.

We used these materials in an eye-tracking study with native speakers of four languages, Catalan, Hindi, Hungarian, and Wolof, spanning four language families, Romance, Indo-Aryan, Finno-Ugric and Congo-Niger, respectively. Data were collected in the original countries where these languages are spoken: the Balearic Islands, Spain; New Delhi, India; Budapest, Hungary; and The Gambia, West Africa. Unlike Catalan, Hindi, and Hungarian, Wolof does not have a written tradition. Of the many grammatical differences among these languages, the relevant one for our study was their adjective position: Hindi and Hungarian have prenominal adjectives, whereas Catalan and Wolof have postnominal ones.

Based on our analysis above, we made two predictions. First, visual context integration during reference interpretation should happen incrementally. This means that speakers of adjective–noun languages should begin reference resolution via property-guided visual search (as determined by the adjective), while speakers of noun–adjective languages should do so via category-guided visual search (as determined by the noun). For example, in Fig. 1, *Top*, a Hindi or Hungarian speaker should begin searching for leather objects when hearing "leather wallet." By contrast, a Catalan or Wolof speaker should begin by searching for a wallet upon hearing the reverse description. Given the sparsity of our displays, we do not predict differences in searching for a target by property or by kind in the zero-competitor baseline (although differences may occur in denser displays). However, adjective position should impact the one-competitor condition. Consider Fig. 1, *Middle*: The prenominal adjective "short" creates a temporary ambiguity between the short candle and the short glass, which can be resolved only by processing the noun. By contrast, when the adjective is postnominal, the noun "candle" provides enough information to identify the target. Therefore, Hindi and Hungarian speakers should be faster to identify the target in the zero-competitor condition than in the one-competitor condition, whereas Catalan and Wolof speakers should reveal no difference between conditions. Note that the reverse would be true if there was a kind competitor, instead of a property competitor, in the one-competitor condition (e.g., two candles but only one short object).

Our second and main prediction is that reference interpretation relies on different pragmatic affordances to maximize efficiency as a function of word order. Consider the two-competitor display in Fig. 1. Upon hearing an adjective, speakers of an adjective–noun language should be able to identify the target, despite the presence of two objects that match the property. Hence, upon hearing "the black," Hindi or Hungarian speakers could anticipate that the target is the lamp if they infer that the speaker is using the adjective contrastively (gloss: If the target were the black chair, why not just say "the chair"?). However, while Hindi and Hungarian speakers can anticipate the target in the two-competitor display, they should experience a temporary ambiguity in the one-competitor display. For instance, in Fig. 1, *Middle*, the scalar adjective cannot be interpreted contrastively (i.e., there is only one candle) and speakers of an adjective–noun language must therefore wait to hear the noun. This advantage in the two-competitor condition relative to the one-competitor one reverses for speakers of noun–adjective languages. Catalan and Wolof speakers should experience a temporary ambiguity in the two-competitor display when hearing "the lamp" because they cannot resolve the reference until they hear the color adjective. However, they should immediately identify the target in the one-competitor display when hearing "the candle." Therefore, Hindi and Hungarian speakers should be faster at identifying the target in the two-competitor condition relative to the one-competitor condition, while the reverse should hold for Catalan and Wolof speakers.

Despite the reverse predictions, the interpretation of the adjective in the two-competitor condition is contrastive regardless of adjective position: Speakers of both adjective–noun and noun–adjective languages understand that the adjective distinguishes the two objects of the same kind (e.g., the two lamps in Fig. 1, *Bottom*). What is different between the two language groups is the pragmatic information available during processing. Speakers of adjective–noun languages can anticipate the noun if they infer that the speaker is preempting an ambiguity (gloss: The speaker must be using "black" to distinguish the two lamps), whereas speakers of noun–adjective languages experience the ambiguity and interpret the adjective contrastively as a result (gloss: The speaker is referring to one of two lamps and uses a color adjective to specify which one).

Results

Fig. 2 shows average participant fixations as they heard the target description. Qualitatively, speakers of adjective–noun and noun–adjective languages performed comparably in the zero-competitor condition. This can be seen in Fig. 2, *Top* row, where speakers of all languages show increased fixations to the target as they process the description. In the one-competitor condition, only participants speaking adjective–noun languages (Hindi and Hungarian) considered the property competitor as a potential target. This can be seen in Fig. 2, *Middle* row, where Hindi and Hungarian speakers initially fixate on both the target and the property competitor (Fig. 2, *Left* and *Center Left* columns), while Catalan and Wolof speakers show immediate fixations to the target alone (Fig. 2, *Center Right* and *Right* columns). Finally, in the two-competitor condition, speakers of noun–adjective languages revealed hesitation between the target and the kind competitor, whereas the hesitation between the target and the property competitor was lesser for speakers of adjective–noun languages. This can be seen in Fig. 2, *Bottom* row, where Catalan and Wolof speakers show roughly equal fixations to the target and to the kind competitor throughout the first half of the

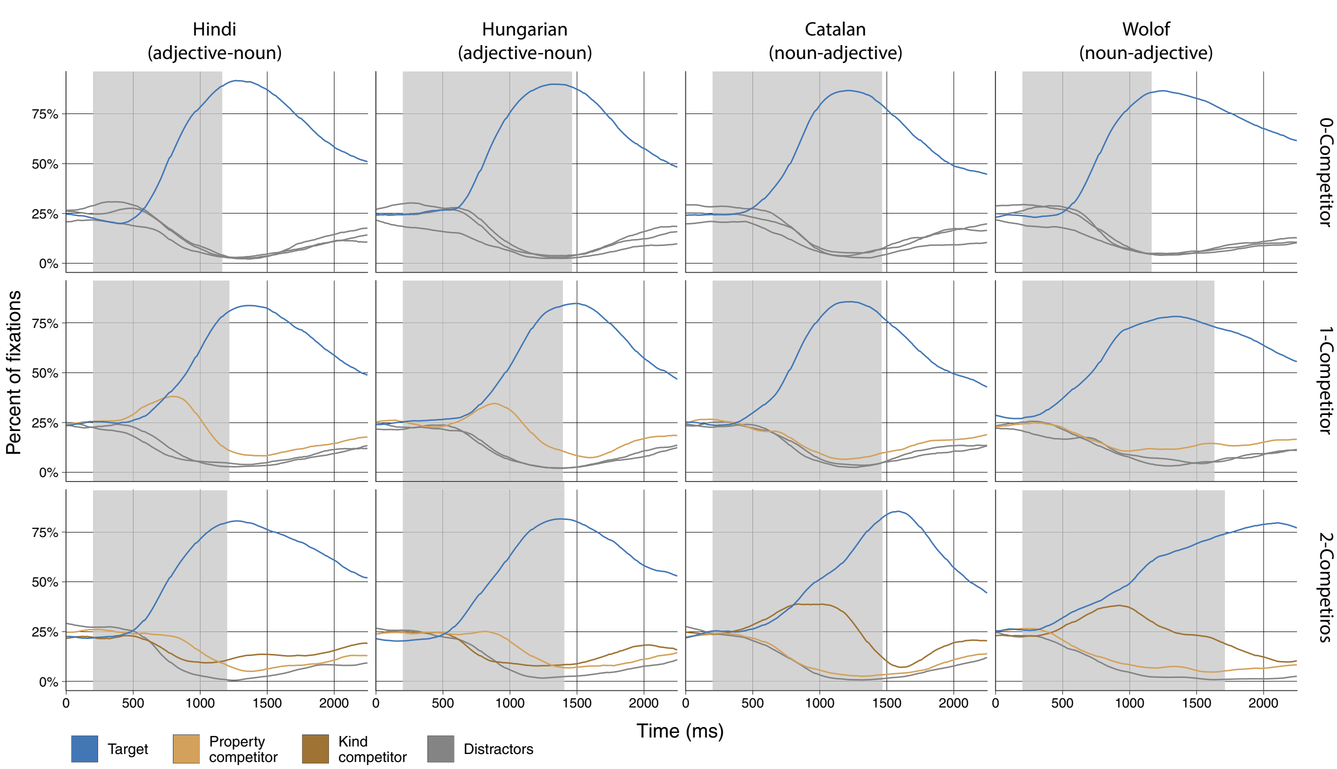

Fig. 2. Percentage of looks to the four objects in a display in the four languages and three conditions of the study during the processing of the target description. Eye-tracking data were collapsed across three adjective types (i.e., color, material, and size). The gray area corresponds to the average target description (always including an adjective).

description, as would be expected if they experienced a temporary ambiguity (Fig. 2, *Center Right* and *Right* columns). By contrast, Hindi and Hungarian speakers show more fixations to the property competitor relative to the other distractors in the display, but their fixations quickly converge on the target (Fig. 2, *Left* and *Center Left* columns). This lesser hesitation suggests that participants recognized that two objects matched the adjective, but then derived a contrastive inference to anticipate the noun.

We evaluated our first prediction by comparing the zero-competitor and one-competitor conditions within each language group. As predicted, speakers of adjective–noun languages fixated more on the target in the zero-competitor condition than in the one-competitor condition (Hindi, 4.98% increase in target fixations in zero-competitor vs. one-competitor condition during target description, $CI_{95\%}$ = 2.13 to 8.05%; Hungarian, 8.22% increase, $CI_{95\%}$ = 6.27 to 10.10%), unlike speakers of noun–adjective languages, who performed comparably across conditions (Catalan, 0.09% increase, $CI_{95\%}$ = −1.84 to 1.98%; Wolof, −0.31% decrease, $CI_{95\%}$ = −2.61 to 1.90%). These findings were also visible at the subject level, with 81.48% ($CI_{95\%}$ = 66.67 to 96.30%; 22 of 27 participants) of Hindi speakers and 96.55% ($CI_{95\%}$ = 93.10 to 100.00%; 28 of 29 participants) of Hungarian speakers fixating more on the target in the zero-competitor than in the one-competitor condition, whereas only 44% ($CI_{95\%}$ = 24.00 to 64.00%; 11 of 25 participants) of Catalan speakers and 42.31% ($CI_{95\%}$ = 23.08 to 61.54%; 11 of 26 participants) of Wolof speakers revealed the same pattern (Fig. 3*A*). These results show that, as predicted by incrementality, speakers of adjective–noun languages resolved reference faster in the zero-competitor than in the one-competitor condition, while speakers of noun–adjective languages showed no difference.

We evaluated our second prediction by comparing the one-competitor and two-competitor conditions within each language group. As predicted, speakers of noun–adjective languages fixated more on the target in the one-competitor condition than in the two-competitor condition (Catalan, 11.70% increase in target fixations in one-competitor vs. two-competitor condition during the target description, $CI_{95\%}$ = 9.87 to 13.60%; Wolof, 11.10% increase, $CI_{95\%}$ = 8.51 to 13.70%), whereas the reverse pattern was observed for speakers of adjective–noun languages (Hindi, −4.12% decrease, $CI_{95\%}$ = −6.98 to −1.40%; Hungarian, −2.22% decrease, $CI_{95\%}$ = −4.37 to −0.13%). Once again, this effect was also visible at the subject level, with 100% ($CI_{95\%}$ = 100.00 to 100.00%; 25 of 25 participants) of Catalan speakers and 96.15% ($CI_{95\%}$ = 92.31 to 100.00%; 25 of 26 participants) of Wolof speakers fixating more on the target in the one-competitor condition than in the two-competitor condition, whereas 74.07% ($CI_{95\%}$ = 59.26 to 92.60%; 20 of 27 participants) of Hindi speakers and 68.97% ($CI_{95\%}$ = 51.72 to 86.21%; 20 of 29 participants) of Hungarian speakers showed the reverse pattern of fixations (Fig. 3*B*). In addition, in the two-competitor condition, Catalan and Wolof speakers fixated more on the kind competitor (96 and 100% of participants, respectively), whereas Hindi and Hungarian speakers fixated more on the property competitor (81.48 and 65.52% of participants, respectively; Fig. 3*C*), as determined by the languages' word order. This analysis reveals how efficient incremental processing allows speakers of adjective–noun languages to derive a contrastive inference in the two-competitor condition, while speakers of noun–adjective languages experience temporary ambiguity until they hear the adjective.

Finally, a cross-linguistic analysis revealed that the average difference in target fixations in the two-competitor vs. one-competitor conditions was reliably different in Hindi vs. Catalan (13.31% difference, $CI_{95\%}$ = 10.72 to 15.75%), Hindi vs. Wolof (12.66% difference, $CI_{95\%}$ = 10.04 to 15.08%), Hungarian vs. Catalan (12.27% difference, $CI_{95\%}$ = 10.14 to 14.46%), and Hungarian vs. Wolof (11.62% difference, $CI_{95\%}$ = 9.47 to 13.78%) (Fig. 4), but was comparable in languages with the same adjective position (*SI Appendix*). These results confirm a cross-linguistic difference in pragmatic reasoning depending on the word order of the language.

Discussion

All languages are processed incrementally and all speakers are under pressure to communicate efficiently (1, 14). Here we showed how these universal forces affect the pragmatic processes underlying reference interpretation. Incrementality determines that visual context integration mirrors a language's word order. For instance, in the two-competitor condition, where the same display included a property competitor and a kind competitor (e.g., a black chair and a blue lamp in Fig. 1, *Bottom*), Hindi and Hungarian speakers considered both the target and the property competitor while processing the adjective, whereas Catalan and Wolof speakers considered both the target and the kind competitor while processing the noun (Fig. 2). Our results also

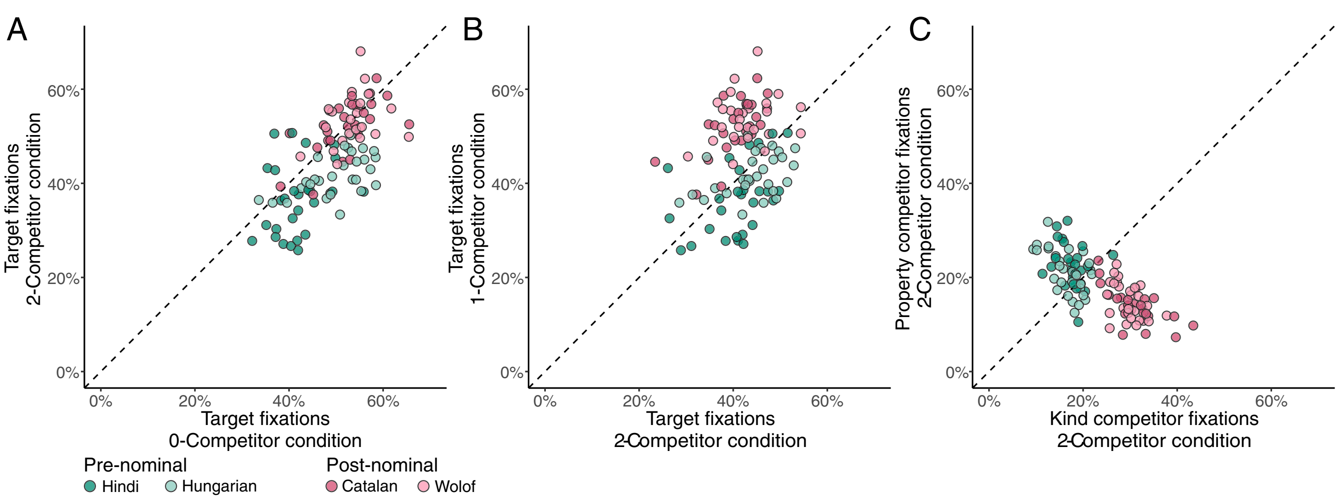

Fig. 3. Subject-level percentage of fixations on the target and on the two competitors during the target description. Each circle represents a participant's average percentage of fixations over all trials regardless of adjective type.

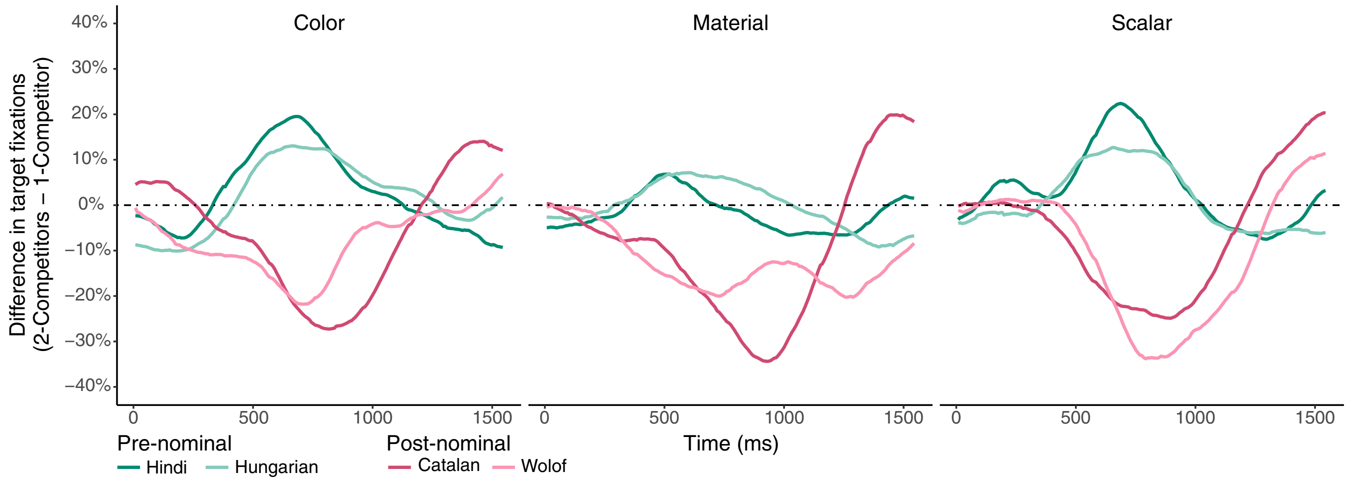

Fig. 4. Difference in target fixations during the description of the target in the two-competitor vs. one-competitor conditions in the three adjective types used in this study. Positive numbers indicate more target fixations in the two-competitor condition relative to the one-competitor condition, and negative numbers indicate more target fixations in the one-competitor condition relative to the two-competitor condition. As predicted, speakers of adjective–noun languages revealed an advantage in the two-competitor condition relative to the one-competitor condition (positive differential score), whereas speakers of noun–adjective languages revealed a disadvantage (negative differential score).

show that language is interpreted efficiently: When the noun provided sufficient information to identify the referent (e.g., when there were two short objects, but only one short candle; Fig. 1, *Middle*), Catalan and Wolof speakers identified the referent as soon as they heard the noun, and did not consider the property competitor when processing the ensuing adjective.

More strikingly, our results show how incrementality and efficiency combined affect not only visual context integration, but also how pragmatic reasoning affects real-time reference interpretation: Hindi and Hungarian speakers were able to anticipate the referent by deriving a contrastive inference, whereas Catalan and Wolof speakers interpreted adjectives contrastively but without deriving the same predictive inference. These results confirm that speakers make the most efficient use of their word order.

The descriptions used in this study were always sufficiently informative, allowing participants to identify the referent without having to infer the intended function of the adjective. Therefore, even Hindi and Hungarian speakers could have waited until the noun to resolve reference in the two-competitor condition, suffering a temporary ambiguity when processing the adjective (analogous to the temporary ambiguity that Catalan and Wolof speakers suffered when processing the noun). The fact that Hindi and Hungarian speakers derived a contrastive inference that allowed them to anticipate the referent shows how the recognition of speaker intentions can drive language interpretation not only at the global level of the message (e.g., Question: "Is John a good student?", Response: "John is good at sports"), but also at the local level of the constituent words. Our results are therefore relevant not only to psycholinguistic models of language processing (2–5, 15, 28, 29), but also to pragmatic and philosophical theories (1, 6, 9, 10, 17, 18) and computational models (7, 8) of the role of speaker intentions in communication.

To date, eye-tracking studies investigating adjective interpretation have mainly focused on English (e.g., refs. 11, 12, 17, 18, 22, and 23) and theoretical frameworks have been developed accordingly. However, most languages position adjectives after nouns, making languages like English a minority (19). Our results highlight the importance of cross-linguistic research for developing nuanced pragmatic theories that explain how language users maximize communicative efficiency given the constraints and affordances of their languages (15, 30).

Our results are proof of concept that, because people interpret language incrementally and efficiently, word order affects pragmatic reasoning. In our study, only speakers of adjective–noun languages could anticipate the referent by inferring the intended function of the adjective. However, this does not imply that only languages with prenominal adjectives allow this form of pragmatic reasoning. Contrastive information can also be encoded in the noun, such that a more specific name may be used to preempt an ambiguity (e.g., the same pet may be called "dog" or "Collie," depending on whether there are other dogs in the scene). Thus, speakers of noun–adjective languages may be able to derive a contrastive inference when processing a noun. Future work needs to chart a taxonomy of different types of pragmatic inference and characterize how speaker intentions constrain real-time interpretation across different languages.

The results of this study are important for our understanding of reference interpretation, but more crucially for the study of pragmatics, as it is generally understood that pragmatic reasoning applies above and across all languages and is normally investigated at a relatively high level of analysis. Here we showed that, like other components of communication, pragmatics are subject to incrementality and efficiency pressures, being constrained by word order, but also exploited to maximize communicative efficiency.

Materials and Methods

Participants. A total of 109 participants were recruited for the study: 25 native speakers of Catalan, 27 of Hindi, 29 of Hungarian, and 26 of Wolof (mean age, 23 y; age range, 18 to 27 y; 62 men). Participants were students at the University of the Balearic Islands (UBI, Mallorca, Spain), the Indian Institute of Technology (IIT, Delhi, India), the Central European University (CEU, Budapest, Hungary), and The Gambia College (TGC, Brikama, The Gambia), respectively. Institutional Review Board approval was obtained from UBI, Massachusetts Institute of Technology (for IIT), and CEU, and the Dean's permission was sought for TGC. All participants signed an informed consent form and received debriefing. Based on previous studies with the same paradigm and on the time available for data collection during fieldwork, sample size was set to 25 to 30 participants per language group. Data collection for two Wolof speakers was interrupted due to a power cut. All participants received monetary compensation.

Materials and Procedure. A list of eight color adjectives (black, blue, brown, green, orange, red, white, and yellow), eight material adjectives (cotton, glass, gold, leather, metal, paper, plastic, wooden, and woolen) and eight scalar adjectives (large, narrow, short, small, tall, thick, thin, and wide) was used in this study. Three displays of four objects were created for each adjective, corresponding with three different conditions: The target was the only object with the relevant property (zero-competitor condition), another object shared the relevant property (one-competitor condition), and another object shared the relevant property and another one was of the same kind as the target (two-competitor condition). For sample items, see Fig. 1 and *SI Appendix*. Target descriptions were first composed in English and then translated to Catalan, Hindi, Hungarian, and Wolof. All materials were recorded by male native speakers of these languages.

The task began with a set of four warm-up trials (*SI Appendix*). The materials were presented in two blocks, with a 10-s break in between each block. The first block consisted of the 24 two-competitor condition trials, combined with 24 filler trials (which were not analyzed) where the target was one of the distractor objects (thus preventing participants from learning to predict the target). To preempt an ambiguity between the two members of the pair, the target description included an adjective in the two-competitor condition, but not in the filler trials (e.g., "the black lamp" in a display with two lamps vs. "the elephant" in a display with a single elephant).

The second block consisted of the 24 one-competitor condition trials and the 24 zero-competitor condition trials. The 24 adjectives selected for the study were used once in the first block of trials and twice in the second one, but accompanying 72 different nouns to avoid that participants could anticipate the target when the adjectives were repeated in the second block of trials.

The division of the conditions in these two blocks was intended to maximize pragmatic reasoning as it has been observed that mixing contrastive and redundant uses of adjectives prevents participants from deriving contrastive inferences (22, 23). In other words, if the speaker used adjectives not only to preempt an ambiguity between two objects of the same kind, but also to describe a singleton object, then the listener would not have pragmatic grounds to anticipate the noun in the contrastive trials. It was for this reason that the two-competitor condition was always presented in the first block of trials. Trial order was randomized individually within each block.

Participants had a long preview of 3 s to be able to fully scan the display before the description of the target started. From the onset of the target description, participants had 3 s to click on the target. Our task design tried to maximize the chances that participants would interpret adjectives contrastively when possible in the visual display. However, the predicted cross-linguistic differences are not dependent on our task design since all participants performed the same task.

Eye movements were recorded with a portable contact-free eye-tracking system (RED-m by SMI; sampling rate, 120 Hz; root mean square, 0.15°; accuracy, 0.5°). The task lasted approximately 20 min.

Data Processing and Analyses Approach. We estimated effect sizes through bootstrapped confidence intervals and drew conclusions based on these intervals. We consider only intervals that do not cross chance as reliable effects. Our conclusions are identical under classical logistic multilevel modeling analyses (*SI Appendix*).

To account for the time it takes participants to launch a saccade, we applied a standard 200-ms correction to all eye-tracking data. In each trial we included data from the onset of the noun phrase (NP) until its end or until the participant selected the target, whichever happened first. Trials where participants did not select the correct target were excluded from analyses. Data in Fig. 2 were obtained by computing percentage of looks to each area of interest (AOI) in each trial on a 200-ms rolling window (such that a point at time x indicates percentage of looks on the range $[x, x + 200\text{ ms}]$). Percentage of looks were then averaged within participants and then across participants within each language group.

For analyses at the subject level, we computed each participant's percentage of looks to each AOI in each trial and then averaged the trials within each condition (output presented in Fig. 3). For analyses that compared conditions within language groups, we further averaged the same data across participants for each condition. Fig. 4 used a standard 1,500-ms window starting from the 200-ms corrected NP onset for all trials.

Data Availability. Experimental materials, looking data, and analysis code are publicly available from the Open Science Framework repository at https://osf.io/t6d2r/ (31).

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