Why searching for a blue triangle is different in English than in Spanish

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Abstract

Color adjectives are normally used to distinguish entities of the same category (e.g., two triangles of different colors), but they are also used redundantly (to refer to a single triangle). We propose that these two adjective uses exploit two types of color contrast: *within-category* and *across-category*. We tested this account in two eye-tracking experiments comparing English and Spanish (e.g., 'the blue triangle' vs. 'el triángulo azul'). Because language processing is incremental, English speakers searched for the target by color (across-category contrast), whereas Spanish speakers searched by shape (within-category contrast). Moreover, the Spanish speakers reversed their visual search when tested in English. More importantly, adjective position also had a significant effect on the production of redundant color adjectives, with English speakers producing more than Spanish speakers in displays where across-category contrast was available. Taken together, our results show how efficiency guides language comprehension and production – even when adjectives are used redundantly.

Keywords: referring expression; referential contrast; redundant adjective; visual search.

1. Introduction

In referential communication tasks, participants must coordinate to arrange various objects in a display. For example, if you wanted me to take a specific triangle from a display of geometrical figures, you would probably describe it differently depending on the other figures in the display.

Thus, if there were other triangles, you would need to mention some distinguishable feature of the one you had in mind (e.g., 'the blue triangle'). However, if there was only one triangle, the referential expression 'the triangle' would be enough. In these situations, adjectives normally have a contrastive function, exploiting a perceptual contrast between objects of the same category (e.g., the difference in size or color between two triangles). However, people often use adjectives redundantly (e.g., to refer to a single triangle), particularly color adjectives (e.g., Sedivy, 2003; Maes et al., 2004; Engelhardt et al., 2006; van der Sluis & Krahmer, 2007; Arts et al., 2011a; Engelhardt & Ferreira, 2014; Rubio-Fernández, 2016). People's redundant use of adjectives is problematic for standard pragmatic theories that assume speakers should not provide their listeners with more information than is necessary (Grice, 1975). More generally, information-theoretic analyses suggest that language is shaped by a pressure to transmit information efficiently (Piantadosi et al., 2011; Levy & Jaeger, 2007; Jaeger, 2010).

There have been two main explanations for the redundant use of adjectives in referential communication. Some have argued that using adjectives redundantly is easier for the speaker, who need not determine whether an adjective is necessary in the context (e.g., whether there are any other triangles, besides the blue one; Pechmann, 1989; Belke & Meyer, 2002; Belke, 2006; Koolen et al., 2013). The reverse explanation has also been proposed, where redundant adjectives are mentioned to help the listener identify the referent (Sonnenschein & Whitehurst, 1982; Mangold & Pobel,1988; Paraboni et al., 2007; Arts et al., 2011b; Paraboni & van Deemter, 2014). In this paper, we propose and test a new account of color overspecification based on the idea that the efficiency of an adjective depends on the referential contrast it exploits.

2. How speakers and listeners establish referential contrast

When speakers use adjectives to exploit a perceptual contrast between objects of the same category, they establish what we will call a *pragmatic contrast* as it is intended to preempt an ambiguity between potential referents. Consider, for example, the Shape Competitor display in Figure 1. Referring to 'the triangle' would be ambiguous, and so the speaker should mention its color or position in order to produce a felicitous referential expression. Pragmatic contrast is established from the speaker's perspective, as it is understood to fulfill a disambiguating intention. From the listener's perspective, however, things can look very different.

Eberhard et al. (1995) showed that participants in their eye-tracking studies identified a referent as soon as the utterance provided enough information to do so. This allows us to make the following prediction: in the Shape Competitor display, listeners should be able to identify the target as soon as they hear 'blue', not having to contrast the two triangles when they hear 'triangle'. This prediction suggests an important asymmetry between the pragmatic contrast that the speaker intends to establish between the two triangles when using 'blue', and the *incremental contrast* that the listener may establish between the blue and non-blue shapes when processing the same adjective.

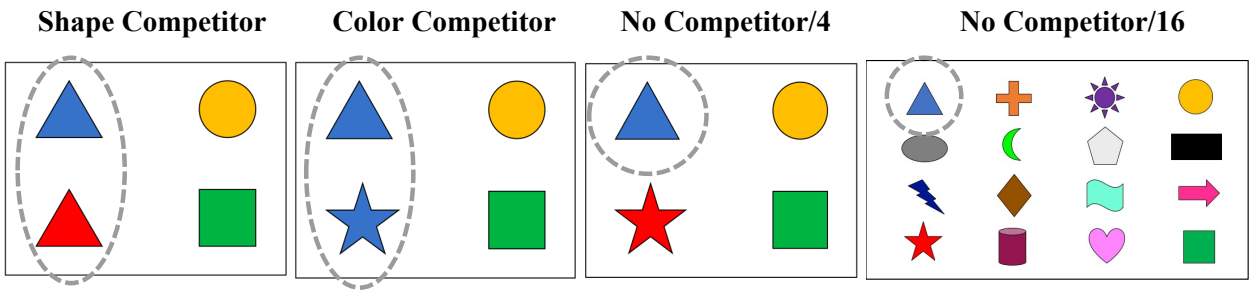

Figure 1: Displays from the critical conditions in the study (from left to right, abbreviated: SC, CC, NC/4 and NC/16). The target was the blue triangle in all displays. SC and CC were used in an eye-tracking task in Experiments 1a and 1b, and NC/4 and NC/16 in a language-production task in Experiment 2.

Rubio-Fernández (2016) characterized the pragmatic contrast established by the adjective 'blue' in the Shape Competitor display as a *within-category contrast*, whereas the incremental contrast resulting from processing this adjective is an *across-category contrast*. This distinction is relevant to the debate on redundant color adjectives: whereas Sedivy (2003, 2004) interpreted the redundant use of adjectives as *noncontrastive*, Rubio-Fernández (2016) argued that color adjectives are normally used redundantly to exploit a color contrast, just one that is established across categories (rather than within). For example, if a speaker referred to 'the blue triangle' in the No Competitor/4 display, the speaker would be establishing a contrast between the only blue shape in the display and all the others.

The distinction between within- vs. across-category contrast sustains the hypothesis that color adjectives can be efficient when used redundantly in referential communication (Rubio-

Fernández, 2016, under revision). English participants in these studies produced redundant color adjectives in polychrome displays where color could guide the listener's search for the referent (as in the No Contrast/4 display), but not in monochrome displays where color did not have any contrastive function (imagine the same display but with 4 blue shapes). In addition, the results of an eye-tracking study using polychrome displays revealed that listeners identified the target faster when the instructions included a redundant color adjective (e.g., 'the blue triangle' vs. 'the triangle'), confirming that across-category color contrast can facilitate target identification. These results suggest that in referential communication, as long as there is a color contrast that can be exploited for visual search, color adjectives can be efficient – even in the absence of a pragmatic contrast.

3. A cross-linguistic study of the processing and production of color adjectives

To date, all studies comparing the use and comprehension of color adjectives have been conducted in English. Sedivy (2003, 2004), for example, investigated adjective production and processing with different lexical categories and different types of adjectives (see also Aparicio et al., 2017). However, the present study was the first to investigate the production and comprehension of color adjectives across two different languages, English and Spanish. The motivation for using these two languages is that they have different Noun Phrase (NP) structures, with English having prenominal adjectives ('the blue triangle') while Spanish has postnominal adjectives ('el triángulo azul'). We hypothesize that, since reference assignment is an incremental process (Eberhard et al., 1995; Spivey et al., 2001), adjective position must play a key role in establishing referential contrast.

Based on the previous discussion, we predict that in Spanish (unlike in English), pragmatic and incremental contrasts should coincide, at least in sparse displays. For example, in processing 'el triángulo azul' in the Shape Competitor display, the listener should first narrow down their visual search to the two triangles and then use color to disambiguate reference. This means that the interpretation process would mirror the contrast that motivated the speaker to use a color adjective, rather than the reverse (as it happens in English).

Our study had two aims. First, we tried to establish the extent to which people's visual search for a referent depends on the language they speak. In Experiment 1a, we used eye tracking to investigate the visual-search strategies of English and Spanish speakers in the same visual

displays. We predicted that when processing 'the blue triangle' vs. 'el triángulo azul', English participants' visual search would be guided by color (regardless of shape), while Spanish participants' would be guided by shape (regardless of color). In Experiment 1b, we tested the same Spanish speakers in the English version of the task to see whether their visual search would reverse in the same testing session.

The second aim of our study was to investigate whether adjective position affects the production of redundant color adjectives when across-category contrast is available. We hypothesized that, if adjective position affects visual search and speakers are efficient, English speakers should produce more redundant color adjectives than Spanish speakers. Thus, in Experiment 2, we elicited referential expressions from English and Spanish speakers using the same visual displays.

4. Experiment 1a

Method

Participants

A group of 25 undergraduates from University College London and 25 undergraduates from the Universidad de las Islas Baleares (Spain) took part in the experiment. Sample size was determined by the time available to collect data at UCL and UIB. The UCL undergraduates were native speakers of English and the UIS undergraduates were native speakers of Spanish. Both groups participated for monetary compensation. All participants reported having normal color vision.

Materials, procedure and predictions

The visual materials included a total of 72 displays with 4 geometrical figures, including 12 critical items from the SC condition and 12 from the CC condition (see Figure 1) plus 48 fillers, which were not analyzed. The first 4 trials were fillers. The target shapes (2 per critical condition) were: circle, diamond, heart, rectangle, square and triangle; and the colors of the shapes were: blue (x2), brown, green (x2), orange (x2), pink (x2), purple, red and yellow. The position of the target and competitor shapes were counterbalanced across trials, and trials were randomized individually for each participant.

The displays were on the screen for 400ms before the instructions started. All instructions were of the form 'Click on the [COLOR ADJECTIVE + SHAPE NOUN]' or 'Haz click en el

[SHAPE NOUN + COLOR ADJECTIVE]'. The instructions were recorded by male native speakers of British English and Castilian Spanish, respectively, who did not stress the adjectives contrastively. For data analysis, a critical time window was calculated for each instruction from the onset of the adjective until the offset of the noun in English, and from the onset of the noun until the offset of the adjective in Spanish. The mean duration of the critical time window was 743ms in English and 996ms in Spanish. We decided on this time window because its structure is parallel in the two languages and would allow observing an early effect of adjective position. We did not use RTs to calculate individual time windows because it introduced the issue of having longer time-windows in those conditions with a competitor.

Participants were told that they were going to listen to a series of instructions to click on different geometrical shapes and their task was to click on the target as fast and accurately as possible. In between trials, they had to click on a cross in the center of the screen to move on to the next trial. This ensured that the mouse cursor was always in the center of the screen at the start of each trial.

Eye movements were recorded with a portable eye-tracking system (RED-m by SMI; SensoMotoric Instruments GmbH, Teltow, Germany) that measured eye position at a sampling rate of 120 Hz and had a spatial resolution (RMS) of 0.1° and an accuracy of 0.5°. Participants were seated about 60 cm from the computer screen. The contact-free set up of the system allowed free head-movement during eye tracking. The experiment lasted approximately 12 minutes. Calibration and validation were performed once at the start of the task.

We predicted that English speakers would search for the target by color, whereas Spanish speakers would search by shape. This means that English participants should suffer interference from the color competitor but not from the shape competitor, whereas the reverse should hold for Spanish participants.

Results

Eye-tracking data were standardly corrected by +200ms in the two experiments in the study. Data and analysis code for all three experiments are available at OSF (https://osf.io/9hw68/).[1] Figure 2 shows the percentage of fixations over time. As predicted, English speakers fixated

[1] Due to conceptual limitations with NHST (Cohen, 1994), we do not perform significance tests and instead present effect sizes with 95% confidence intervals.

more on the target when there was a shape competitor (53.9%; 95% CI: 49.2-58.6) than when when there was a color competitor (42.1%; 95% CI:39.2-45.1), with a reliable difference across conditions (Target advantage in CC = 11.8%; 95% CI: 6.05-17.43). By contrast, Spanish speakers fixated less on the target when there was a shape competitor (40.5%; 95% CI: 37.4-43.6) than when there was a color competitor (52.5%; 95% CI: 48.8-56.0) (Target advantage in SC = 12%; 95% CI: 7.07-16.63). Consistent with this, English speakers fixated more on the target than Spanish speakers did when there was a shape competitor (Difference = 13.4%; 95% CI: 7.58-19.07), whereas Spanish speakers fixated more on the target than English speakers did when there was a color competitor (Difference = 10.4; 95% CI: 5.59-15.05).

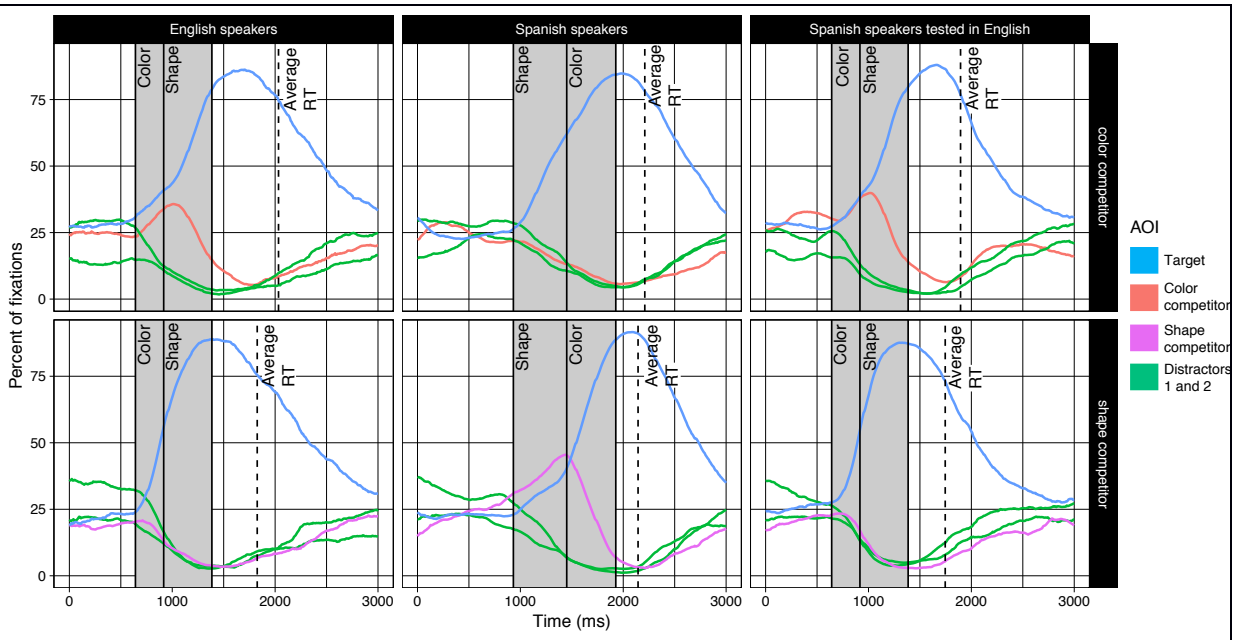

Figure 2. Percentage of looks over time. At each time point, the curve represents the percentage of fixations in the previous 200ms. The grey region represents the duration of the NP and the dashed lines represent participants' average reaction times.

Figure 3 shows the percentage of fixations on the target (panel a) as well as on the competitor (panel b). As predicted, Spanish speakers suffered more interference from the shape competitor relative to English speakers (Interference difference = 21.7%; 95% CI: 18.13-25.23). By contrast, English speakers suffered more interference from the color competitor relative to Spanish speakers (Interference difference = 15.4%; 95% CI: 12.14-18.86).

5. Experiment 1b

Method

Participants

The same group of 25 undergraduates from the Universidad de las Islas Baleares who took part in the Spanish version of Experiment 1a were tested again in the English version immediately after. Participants reported having an intermediate level of English. None of the participants reported being Spanish-English bilinguals. One of the participants did not perform the task because they did not feel comfortable being tested in English.

Materials, procedure and predictions

Participants were tested in the English version of the task reported in Experiment 1a. We predict that incrementality should be powerful enough as to reverse Spanish participants' visual search strategy (i.e. they should search for the target by color, not by shape).

Results

In contrast to the results from Experiment 1a, Spanish speakers' looking pattern was reversed when tested in English (Figure 2). Participants now fixated more on the target when there was a shape competitor (55.6%; 95% CI: 52.4 - 59.1) relative to when there was a color competitor (40.3%; 95% CI:37.2 - 43.6), with a reliable difference between conditions (Advantage in SC = 15.3%; 95% CI: 10.75 - 19.98). This pattern was reliably different from their looking pattern when tested in Spanish, both when there was a shape competitor (Difference = 15.1%; 95% CI: 7.58 - 19.07) and a color competitor (Difference = 12.2%; 95% CI: 7.29-16.94). Consistent with this, participants' pattern of looks was no longer different from that of English speakers when there was a shape competitor (Spanish-English difference = 1.7%; 95% CI: -3.97 - 7.78) or when there was a color competitor (Spanish-English difference = -1.8%; 95% CI: -6.14 – 2.74). Similarly, Spanish speakers' interference was reversed (Figure 3). Participants now showed increased interference from the color competitor (interference increase = 18.5%; 95% CI: 15.51 – 21.81) and reduced interference from the color competitor (interference decrease = 20.3%; 95% CI: 17.08 - 23.57).

The interaction between language and competitor type in the looking patterns also appeared at the subject-level. 88% (n=22) of English speakers and 96% (n=24) of Spanish

speakers tested in English fixated more on the target when there was a shape competitor than when there was a color competitor. By contrast, 88.5% (n=23) of Spanish speakers tested in Spanish fixated more on the target when there was a color competitor than when there was a shape competitor. The results of competitor interference were consistent with this. 92% (n=23) of English speakers and 100% (n=25) of Spanish speakers tested in English fixated more on the competitor when it was a color match than when it was a shape match. By contrast, 100% (n=26) of Spanish speakers tested in Spanish fixated more on the competitor when it was a shape match than when it was a color match (for data visualizations, see Supplemental Materials).

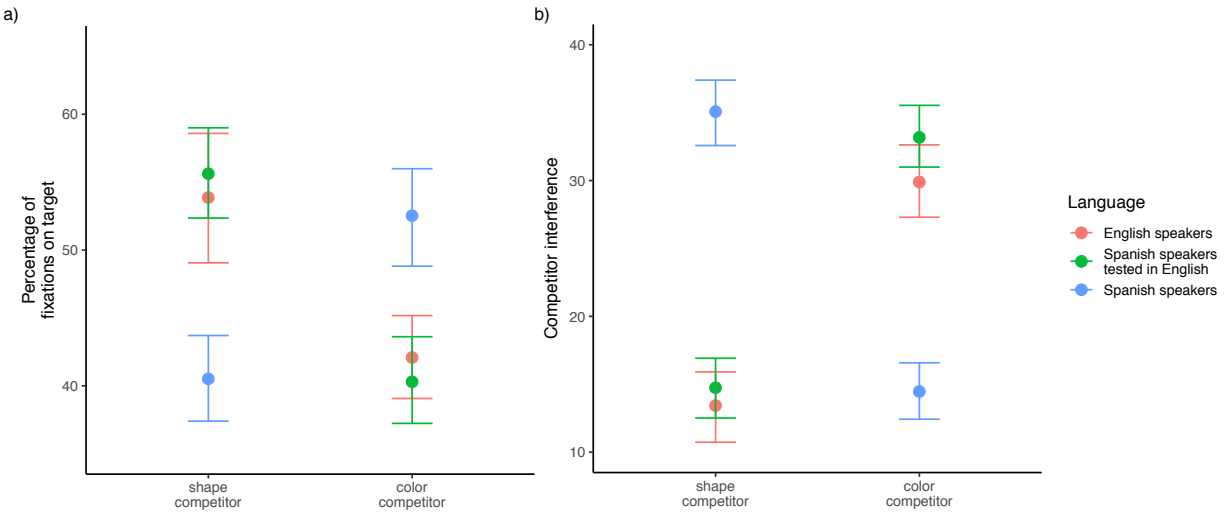

Figure 3. a) Average percentage of fixations on the target during the NP (y-axis) when there was a shape competitor or a color competitor in the display (x-axis). b) Percentage of fixations on the shape competitor and on the color competitor during the NP. In both plots, vertical lines show 95% bootstrapped confidence intervals.

6. Experiment 2

Method

Participants

A new group of 22 undergraduates from University College London and 22 undergraduates from the University of the Balearic Islands (Spain) took part in the experiment. Sample size was determined by the time available to collect data at UCL and UIB. The UCL undergraduates were native speakers of English and the Baleares undergraduates were native speakers of Spanish.

Both groups participated for monetary compensation. All participants reported having normal color vision.

Materials, procedure and predictions

Two types of displays were created, one for the Experimenter (including 20 displays of shapes) and another one for the participant (including empty grids with a cross indicating the position of the target in the Experimenter's display). The target shapes were the following: circle, cross, diamond, heart, oval, rectangle, square, star, sun and triangle; and came in the following colors: black, blue, brown, green, grey, orange, pink, purple, red and yellow. Target position was counterbalanced across trials. Ten displays from the NC/4 condition were used for the first block of trials and another 10 displays from the NC/16 condition for the second block of trials (see Figure 1).

The displays were shown on a computer monitor placed in front of the Experimenter. The participant was sitting beside and behind the Experimenter and their task was to ask the Experimenter to click on the target figure in each trial. In order to determine which figure was the target, participants were given printouts of a series of 20 grids with a cross indicating the position of the target in the Experimenter's display. The instructions stressed that the Experimenter did not know which figure was the target in each trial, and that all figures in the displays had different shapes. Color adjectives were therefore redundant in all trials.

Participants were told that their responses would serve as control data in a study originally designed for children. This was done in order to avoid that participants may become self-conscious and start producing unnatural responses because of the simplicity of the task (this was observed in a pilot study where participants described the shapes in great detail).

Participants' requests were recorded and later coded as redundant or not redundant by two blind coders. Only referential expressions including both an adjective and a noun (e.g., 'The blue triangle') were coded as redundant. The task lasted less than 10 minutes.

Since color adjectives guide visual search in prenominal position, it would be generally more efficient for English speakers to produce redundant color adjectives than for Spanish speakers. However, the relative efficiency of a redundant adjective depends not only on the position of the adjective, but also on the density of the display. Thus, in relatively dense displays, postnominal color adjectives would increase in efficiency since the interlocutor may not be able to identify the referent by the time they finish processing the noun. We therefore predicted that

English speakers would produce more redundant color adjectives than Spanish speakers in 4-shape displays but not in 16-shape displays. Overall, if speakers are efficient in their choice of referential expression, the production of redundant color adjectives should increase from 4-shape displays to 16-shape displays in both English and Spanish.

Results

Figure 4 shows the percentage of times participants used color words as a function of the number of shapes in the display. When there were only 4 shapes, English speakers used color words 37.3% of time (95% CI:18.2-55.9) whereas Spanish speakers used color words only 2.73% of the time (95% CI: 0-5.0), and these rates were reliably different (difference = 34.57%; 95% CI: 14.09-53.64). In the display with 16 shapes, English speakers now produced color words 80.5% of time (95% CI:67.7-95.9), and this rate was reliably higher than their production in the 4-shape condition (difference = 43.18%; 95% CI:19.55-68.18). Spanish speakers also produced more color words in the 16-shape condition at 61.4% (95% CI: 45.9-77.7), which was reliably higher than their production in the 4-shape condition (difference = 58.64%; 95% CI:42.72-75.45) but was no longer lower than the English speakers' rate (difference = 19.09; 95% CI: -2.27 – 40.9).

The overall pattern of results from Experiment 2 was also visible at the subject-level. 50% (n=11) of English speakers used more color words in the 16-shape condition than in the 4-shape condition, 50% (n=11) used the same amount (8 of these participants had used color words in every trial of the 4-shape block, making it impossible for them to use more color words in the 16-shape block), and 0% used fewer color words. Among Spanish speakers, 82% (n=18) used more color words in the 16-shape condition than in the 4-shape condition, 18% (n=4) used an equal amount, and 0% used fewer color words (see Supplemental Materials).

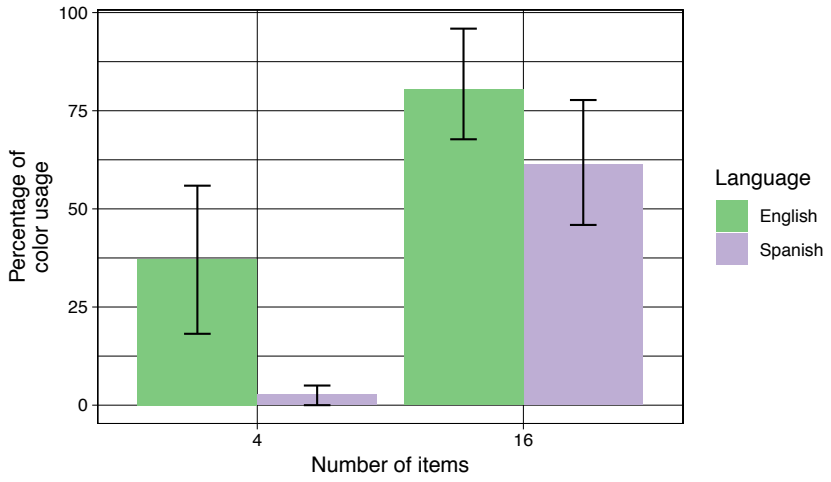

Figure 4. Percentage of times speakers used redundant color adjectives in each condition and language. Vertical bars show 95% bootstrapped confidence intervals.

7. General discussion

Adjective position (prenominal vs. postnominal) determines how listeners identify a referent. When searching for the same blue triangle, English participants searched by color, whereas Spanish participants searched by shape. Moreover, when the same Spanish participants were tested in English, their visual search was reversed. The effect of adjective position on visual search demonstrates that reference assignment is an incremental process. As predicted, adjective position also affected the rates of redundant color adjectives produced by English and Spanish speakers, with English speakers producing higher rates than Spanish speakers. We interpret these results as evidence that color adjectives are normally used to exploit a color contrast in the visual context: either a within-category contrast or an across-category contrast.

We also distinguished pragmatic contrast (the within-category contrast that may prompt a speaker to use a color adjective) from incremental contrast (the kind that listeners establish as they process a referential expression). The results of our eye-tracking experiments show how pragmatic and incremental contrasts tallied in Spanish (where both speaker and listener established a within-category contrast when there were two shape competitors) but did not always tally in English (where the speaker sometimes used a color adjective to establish a

within-category contrast but the listener established an across-category contrast when processing the same adjective).

These results highlight the importance of performing cross-linguistic research when trying to understand how people use and interpret language. While most eye-tracking studies on adjective interpretation have been conducted in English, according to the World Atlas of Language Structures (Dryer, 2013), of a sample of around 1400 languages, less than 400 have prenominal adjectives (like English), whereas almost 900 have postnominal adjectives (like Spanish).

Our results also speak to the long-standing debate on language and thought (Wolff & Holmes, 2011). Research in that area has typically looked at the effect of language on non-linguistic tasks such as perception, categorization and memory (Lupyan, 2012). Borrowing Marr's distinction (1982; Geurts & Rubio-Fernández, 2015), we document how language structure can determine the procedures underlying a pragmatic computation. While both English and Spanish participants in our language-comprehension task successfully assigned reference to the expression 'the blue triangle'/'el triángulo azul', their eye movements revealed that English participants were searching for a blue referent, whereas Spanish participants were searching for a triangular one. Crucially, these different procedures also affected the way English and Spanish participants used adjectives in the mirror, language-production task. This suggests that language can affect thought by determining the processes underlying a pragmatic function, such as reference assignment and reference production.

Above and beyond the clear differences in how English and Spanish speakers process and use color adjectives, our results highlight a fundamental commonality: efficiency drives both the comprehension and the use of color adjectives across languages. When Spanish speakers were tested in English, they did not suffer interference from the shape competitor (as they had done in Spanish) and were able to search efficiently by color. In other words, speakers were able to identify a referent as soon as they had enough information to do so, regardless of the language they were tested in. Likewise, both English and Spanish participants produced more redundant color adjectives in dense displays than in sparse displays, with the significant difference observed between the two languages in the 4-shape condition disappearing in the 16-shape condition. These results suggest that speakers use color adjectives efficiently, even without a pragmatic contrast.

Future studies should investigate whether across-category contrast is equally important for different types of adjectives. For example, scalar adjectives are normally interpreted in relation to other entities of the same category (e.g., 'the large triangle'), so within-category contrast is likely to be more important for their interpretation than for that of absolute adjectives, such as color. On the other hand, it is possible that the visual salience of color sets color adjectives apart from other absolute adjectives, making across-category contrast particularly important for their use and interpretation.

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