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Concepts Are Restructured During Language Contact: The Birth of Blue and Other Color Concepts in Tsimane'-Spanish Bilinguals

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Abstract

Words and the concepts they represent vary across languages. Here we ask if mother-tongue concepts are altered by learning a second language. What happens when speakers of Tsimane', a language with few consensus color terms, learn Bolivian Spanish, a language with more terms? Three possibilities arise: Concepts in Tsimane' may remain unaffected, or they may be remapped, either by Tsimane' terms taking on new meanings or by borrowing Bolivian-Spanish terms. We found that adult bilingual speakers (n = 30) remapped Tsimane' concepts without importing Bolivian-Spanish terms into Tsimane'. All Tsimane' terms become more precise; for example, concepts of monolingual *shandyes* and *yụshñus* (~green or blue, used synonymously by Tsimane' monolinguals; n = 71) come to reflect the Bolivian-Spanish distinction of *verde* (~green) and *azul* (~blue). These results show that learning a second language can change the concepts in the first language.

Keywords

bilingualism, conceptual representation, language change

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Introduction

The majority of the world's population speaks two or more languages (Bacon-Shone & Bolton, 1998; Grosjean, 2022), with the number of bilingual speakers increasing over time (Bacon-Shone et al., 2015; Ryan, 2013) and with languages coming into contact more often (Ann, 2001; Appel & Muysken, 2005; Silva-Corvalán, 1997).

Language contact is sometimes assumed to have no impact on the concepts retained in each language: This assumption is implicit in original studies of color-naming differences across languages, as in the case of Berlin and Kay (1969), who proposed a universal pattern in how color words enter a language's lexicon based on data from speakers of diverse languages who were mostly residents of the United States and bilingual in English. Language contact is a major source of language change, such as, when words are borrowed from other languages (e.g., Aikhenvald, 2003; Haugen, 1950), grammar is simplified (e.g., Silva-Corvalán, 1986), or pronunciations are changed (e.g., Thomason, 2001). Although it has primarily been shown that language contact often affects the form of language (e.g., morphemes; Owens, 1999), phonemes (Deterding, 2010), or syntax (Håkansson et al., 2002), here we ask whether concepts in a language are altered when a second language is acquired by a speaker.

The possible restructuring of concepts in the bilingual mind has been difficult to probe in the past for several reasons. First, past work has focused on WEIRD

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societies (Western, Educated, Industrialized, Rich, and Democratic; Henrich et al., 2010), where speakers have similar cultures with similar conceptual representations, leading to pairwise translation equivalents between languages (e.g., Jarvis & Pavlenko, 2012). Second, changes in the concepts associated with words that do not have pairwise translation between languages are hard to probe because these concepts are typically abstract and idiosyncratic. Examples include *schadenfreude* in German and *saudade* in Portuguese, which cannot be translated as a single English word (for other examples, see https://languagelog.ldc.upenn.edu/nll/?p=1081).

There have been attempts to address whether learning a second language alters the concepts in the first language (Athanasopoulos, 2009; Athanasopoulos et al., 2010, 2011; Boroditsky, 2001; Cook et al., 2016; He et al., 2019). This might not involve an impact of the new language on perceptual discriminability but rather on the concepts that perceptions map onto, so that learning a second language affects the concepts in the first language. Boroditsky (2001) explored how English speakers change the way they speak about time upon learning Mandarin; Cook et al. (2016) explored how Japanese speakers' biases for word-meaning generalization changed upon learning English (Cook et al., 2016); Athanasopoulos (2009), Athanasopoulos et al. (2010, 2011) and He et al. (2019) investigated whether native speakers of languages with separate color terms for dark and light blue changed their categorization of these two color terms upon learning a language with only one blue color term. Pinning down and replicating the small effect sizes often evident in these kinds of studies has been challenging (January & Kako, 2007), possibly because the cultures of the pairs of languages are similar. For instance, in the case of color concepts, the set of terms in Greek and English studied in Athanasopoulos (2009), Athanasopoulos et al. (2010, 2011) differ only by one term (i.e., blue vs. light and dark blue). Given that the number of color terms used consistently by speakers of a language varies from two to 11 and above (Berlin & Kay, 1969; Conway et al., 2020; Gibson et al., 2017; Kay & Maffi, 1999; Regier et al., 2015; Zaslavsky et al., 2018, 2022), we speculated that it might be easier to investigate conceptual changes in the color-labeling system in bilingual speakers who speak languages that are on different ends of the spectrum of the number-of-color-words scale—that is, a language that has a few color terms used consistently by its population and a language that has at least 11 color terms used consistently (as in industrialized populations, which typically have 11 or 12 common terms). Probing vastly different cultures would potentially yield larger differences.

Statement of Relevance

Languages and culture conceptualize the world in different ways. For instance, with color terms, some languages have three color terms, whereas others have 12 or more. What happens if you learn a new language that has more color concepts than your mother tongue? The question is relevant because contact between cultures is increasing with globalization. We took up the question by studying how speakers of Tsimane', an Amazonian language with a single word encompassing blues and greens, behave when they learn Bolivian Spanish, a language that distinguishes two categories of blue and one of green. We found that the consistency of Tsimane' color terms increases among the Tsimane'-Spanish bilingual speakers and that the bilinguals develop different words in Tsimane' that distinguish blue and green. The work provides a compelling example of language and culture influencing cognition and suggests that language contact drives rapid language change over time.

Two languages with large differences in their use of color words are Bolivian Spanish and Tsimane'. Like other industrialized societies, Bolivian Spanish speakers tend to use 12 color terms consistently: *blanco* (white), *negro* (black), *rojo* (red), *verde* (green), *amarillo* (yellow), *celeste* (light blue), *azul* (dark blue), *rosado* (pink), *anaranjado* (orange), *violeta* (purple), and *gris* (gray). Tsimane', meanwhile, is a language belonging to a farmer-forager community in Bolivia, and like many nonindustrialized societies, Tsimane' speakers use only a few color terms consistently, such as *jaibas* (~white), *tsincus* (~black), and *jäinäs* (~red). Despite the apparent differences in the number of terms used consistently, languages with fewer consistent color terms, such as Tsimane', still have rich conceptual knowledge of color distributed across the population (Lindsey et al., 2015). A survey across Tsimane' participants has revealed that there are at least four different terms used for the English word "yellow": *chames*, *kuchikuchi-yeisi, tsundyes, ifu-yeisi* (Malik-Moraleda et al., 2022). And although there are two terms for "green" and "blue" that most people use (*shandyes* and *yụshñus*), these are used interchangeably by most Tsimane' speakers for all of the green-blue color space (a "grue" color category).

We investigate what impact, if any, learning Spanish has on how Tsimane' speakers talk about and conceive

Table 1. Linguistic Profile of the Bilingual Population

Language	Age of acquisition	Percentage of use (*SD*)	Self-rated proficiency		Years of immersion (*SD*)
			Speaking (*SD*)	Listening (*SD*)	
Tsimane'	Native	74 (14)	1.04 (0.2)	1.12 (0.3)	10.5 (2.67)
Spanish	12.4 (3.32)	26 (14)	2.67 (0.8)	2.90 (0.8)	8.49 (1.04)

Note: Participants were asked to rate their proficiency from *1* (excellent) to *5* (beginner). "Years of immersion" refers to the amount of time the speaker has lived in a community where the dominant language is either Tsimane' or Spanish.

of colors. One possibility is that the meanings of Tsimane' color words remain unaltered. That is, given that Tsimane'-Spanish speakers will likely use Tsimane' color words only with other Tsimane' speakers, these words may retain their particular mappings onto the color space. A second possibility is that Tsimane'-Spanish speakers might borrow Spanish color terms; borrowing occurs when some features of a foreign language are incorporated into a group's native language (Thomason & Kaufman, 1992). A third possibility is that Tsimane'-Spanish speakers might repurpose or restructure Tsimane' color terms, so that the meanings of the terms become more consistent and more similar to the meanings present in Spanish (Lucas, 2015).

We test this hypothesis by conducting color-naming studies in three groups of participants—Tsimane' monolinguals, Tsimane'-Spanish bilinguals, and Spanish monolinguals—and analyzing the results within an information theoretic framework.

Open Practices Statement

All data, code and materials are available in the following OSF repository: https://osf.io/3zg2k. This was not a preregistered study.

Method

Participants

A total of 152 participants took part in the study: 71 Tsimane' monolinguals, 30 Spanish monolinguals, and 30 Tsimane'-Spanish bilinguals. Sample size was determined by the number of available speakers that we could test within the 2 weeks we were visiting the community. No participants were excluded for any reasons. All bilinguals first learned to read Tsimane' and then Spanish. Of the 30 Tsimane'-Spanish bilingual speakers, 22 completed a language questionnaire and indicated that they generally rated themselves to be more proficient in Tsimane' than in Spanish (see Table 1 for details; note that all 30 bilingual participants were included in the study even if they had not completed the language questionnaire). All participants were screened for color-blindness (Neitz & Neitz, 2001) prior to the study, received compensation for their time, and gave informed consent as required by the Committee on the Use of Humans as Experimental Subjects. The committee reviewed and approved this research.

Tasks

Participants took part in three tasks, previously used by Gibson et al. (Conway et al., 2020; Gibson et al., 2017). The first task was a Munsell chip-labeling task, in which they were asked to name 84 colored chips sampled from the standard Munsell array of colors and presented to them in a random order. Second, participants completed a color-selection task in which they were presented with all 84 chips in the Munsell array (see Fig. S1) and were asked to point at the chips they would label with each of the Tsimane' or Spanish terms. Third was a focal-selection task, in which participants indicated which chip they considered to be the best exemplar of each of the Tsimane' color or Spanish color terms. Bilingual participants first completed all three tasks in Tsimane' (n = 16) and then in Spanish, or vice versa (n = 14). All tasks were performed indoors under controlled lighting conditions with the use of a light box (nine phosphor broadband D50 color-viewing system, model PDV-e, GTI Graphic Technology, Inc., Newburgh, NY).

Results

We were interested in exploring whether the Tsimane' color terms used by Tsimane'-Spanish bilinguals are different from those of Tsimane' monolinguals. To explore this question, we conducted four related analyses: first, measuring the average surprisal values across groups; second, measuring the change in modal terms across groups; third, a more focused analysis measuring the change in distribution of chips within a particular color term; and fourth, an analysis of the overlap between neighboring color pairs. The first two analyses used the responses from the Munsell chip-labeling task, whereas the latter two used the responses from the color-selection task.

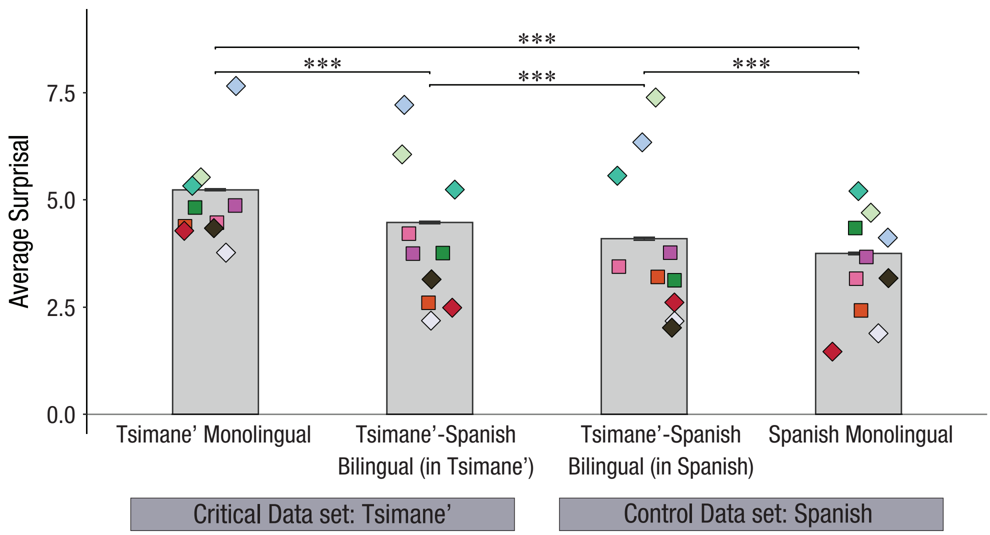

Fig. 1. Average surprisal value in each language across all chips (bar graphs) as well as for a sample of 10 chips from the Munsell board, which were selected as follows: The chip with the minimum and maximum average surprisal in each language was selected first, resulting in six color chips presented as diamonds in the plot, along with four random chips presented as squares in the plot. (Some groups had the same chips with minimum/maximum average surprisal, so that is why only 6, not 8, chips are depicted in the figure.) All chips were then plotted across all languages. Note that average surprisal values were calculated for all chips but that only a selection is represented in this figure. Error bars represent standard errors of the mean. Please see Figure S3 in the Supplemental Material for a version of this figure that is accessible to color-blind populations. Asterisks represent statistically significant differences.

Average surprisal values across groups

Average surprisal was computed for each chip on the Munsell array using the following equation (Gibson et al., 2017; Regier et al., 2015):

$$S(c) = \sum_{w} P(w|c) \log \frac{1}{P(c|w)}. \quad (1)$$

This equation gives a surprisal score for each color chip *c*, which aggregates over all possible words that might be used for that chip and which intuitively corresponds to the overall number of guesses that would be required, on average, to guess a chip in a communication game. For example, suppose that an English speaker picks one chip from the Munsell board and labels it "red" and labels another chip "turquoise." There are fewer color chips that would be labeled "red" than "turquoise" by typical English speakers. The red chip can therefore typically be identified with fewer guesses, so that its average surprisal is lower. Average surprisal is computed by summing together a value for each word w that might have been used to label c, which is calculated by multiplying $P(w|c)$ (the probability that word w is used to refer to chip c) by $-\log(P(c|w)$—the surprisal associated with chip c being referred to by word w. For simplicity, $P(c|w)$ is estimated assuming a uniform prior on $P(\mathrm{c})$; other priors give similar results for our purposes here (see Zaslavsky et al., 2018, for a comparison of different priors).

We average over color scores *S(c)* to get an average surprisal for speakers in each of our groups. In order to test whether these differences are significant across the color grids, a random permutation test was carried out over *S(c)* scores for each of the four comparisons above using the R package *rcompanion* (Mangiafico & Mangiafico, 2017). The goal of these tests is to ascertain whether the observed difference in *S(c)* scores between two groups of speakers could have occurred by chance. Thus, the logic of the test is to compare the actual *S(c)* score differences between two groups of participants (e.g., between monolingual Tsimane' speakers and Spanish speakers) to a statistical baseline in which participants are randomly assigned to the two groups. All random permutation tests were performed with 1,000 iterations, and p values were adjusted using the false discovery rate method. As seen in Figure 1, we observed that the average surprisal in monolingual Tsimane' speakers (S = 5.16) was greater than the average surprisal in Spanish speakers (S = 3.70, p < .001), in line with Gibson et al. (2017). Furthermore, we see that the average surprisal in monolingual Tsimane' speakers

(S = 5.16) is greater than Tsimane'-Spanish bilingual speakers doing the task in Tsimane' (S = 4.42, p < .001). The average surprisal value in Tsimane'-Spanish bilingual speakers doing the task in Tsimane' (S = 4.42) is greater than the average surprisal value of Tsimane'-Spanish bilingual speakers doing the task in Spanish (S = 4.02, p = .034). Last, we see that the average surprisal in Tsimane'-Spanish bilingual speakers doing the task in Spanish (S = 4.02) is greater than the average surprisal of monolingual Spanish speakers (S = 3.70, p = .032).

Taken together, these results suggest that Tsimane' bilingual speakers do alter Tsimane' terms upon learning Spanish, given that the average surprisal value for their color terms is lower than that of Tsimane' monolingual speakers. These results speak against one of the hypotheses presented in the introduction: that Tsimane' bilinguals' color system remains the same upon learning Spanish. It does not, however, allow us to differentiate whether Tsimane' bilinguals are borrowing Spanish color terms or whether they are restructuring Tsimane' color terms. To differentiate between these two possibilities, we will look at how each color chip in the Munsell array is being labeled by participants in each group.

Changes in modal terms across groups

We proceeded to explore how color-labeling changes across participant groups by looking at the chips labeled with a similar color term by the majority of the population, which we will call *modal-majority terms*, where over 50% of the participants used the same term for the color chip. As shown in Figure 2, Tsimane' monolingual speakers had five terms satisfying this criterion: *jäinäs* (red), *tsincus* (black), *chames* (yellow), *itsidyeisi* (purple), and *cafedyeisi* (brown). (Note that there were no white or gray chips being queried in this set.) Although the Tsimane' have five modal-majority terms, a random permutation test indicates that the consensus across these modal terms is significantly lower for Tsimane' monolinguals (M = 0.67) than for Spanish monolingual (M = 0.87, p < .001); in other words, Tsimane' monolinguals' modal terms are less consistent than those of Spanish monolinguals. Tsimane'-Spanish bilinguals use two more modal-majority terms in Tsimane': *shandyes* (green) and *yụshñus* (blue). Spanish monolingual speakers and Tsimane'-Spanish bilingual speakers completing the task in Spanish used the same nine Spanish modal-majority terms for these color chips: *rojo* (red), *negro* (black), *anaranjado* (orange), *rosado* (pink), *amarillo* (yellow), *verde* (green), *celeste* (light blue), *azul* (dark blue), and *violeta* (violet). Given that the Spanish modal-majority term *celeste* (light blue) is not represented in Tsimane' bilinguals and that the two modal-majority terms used in Tsimane' (*shandyes* ~ green, *yụshñus* ~ blue) are reused Tsimane' words, it is likely that we are observing restructuring of Tsimane' terms. However, given that these two terms are not present in the Tsimane' monolinguals' modal terms, we next will examine how Tsimane' monolingual speakers use these terms.

Changes in the distribution of chips for each color term across language groups

It is apparent from Figure 2, which shows the proportion of the participant population using a dominant label for a particular chip, that a *shandyes* (green) and *yụshñus* (blue) color space emerges that is not present in Tsimane' monolinguals. It is possible that Tsimane' monolinguals are using these two terms synonymously for these color chips. Given that the Munsell chip-labeling task restricts people to providing one word for each chip, it is difficult to see if a chip is compatible with multiple labels. We thus looked at the color-selection tasks, in which participants selected all the chips within the Munsell array that they would label with each color term. Given that the biggest contrast in Figure 2 is between Tsimane' bilinguals and monolinguals, we plot in Figure 3 the results for the color-selection task for all the modal terms that exist in Tsimane' bilinguals (i.e., *jäinäs*, *shandyes*, *yụshñus*, *chames, cafedyeisi, itsiyeisi*; see Fig. 2).

Figure 3 shows that Tsimane' monolinguals indeed selected similar sets of color chips for the terms *shandyes* (green) and *yụshñus* (blue), confirming that Tsimane' monolinguals have a common green-blue (i.e., grue) color category. A second pattern can be observed from Figure 3: the number of chips that are encompassed by each of the modal color terms is larger for the Tsimane' monolingual group compared to the Tsimane' bilingual group. For example, Tsimane' monolingual *jäinäs* (red) and *chames* (yellow) contain more chips on the Munsell array than the Tsimane' bilingual or either Spanish correlate of these colors.

To test whether the distribution of the chips for each color term differs between groups, we carried out chi-square tests between group pairs for each color term. For each color term, we first calculated for each chip the number of times participants within a group had chosen that chip as an example of the color term and then compared these frequencies across all chips between two groups using a chi-square test (see Table S3 in the Supplemental Material). Between Tsimane' monolinguals and Spanish bilinguals, all color terms except *itsidyeisi* (purple) had different distributions. In

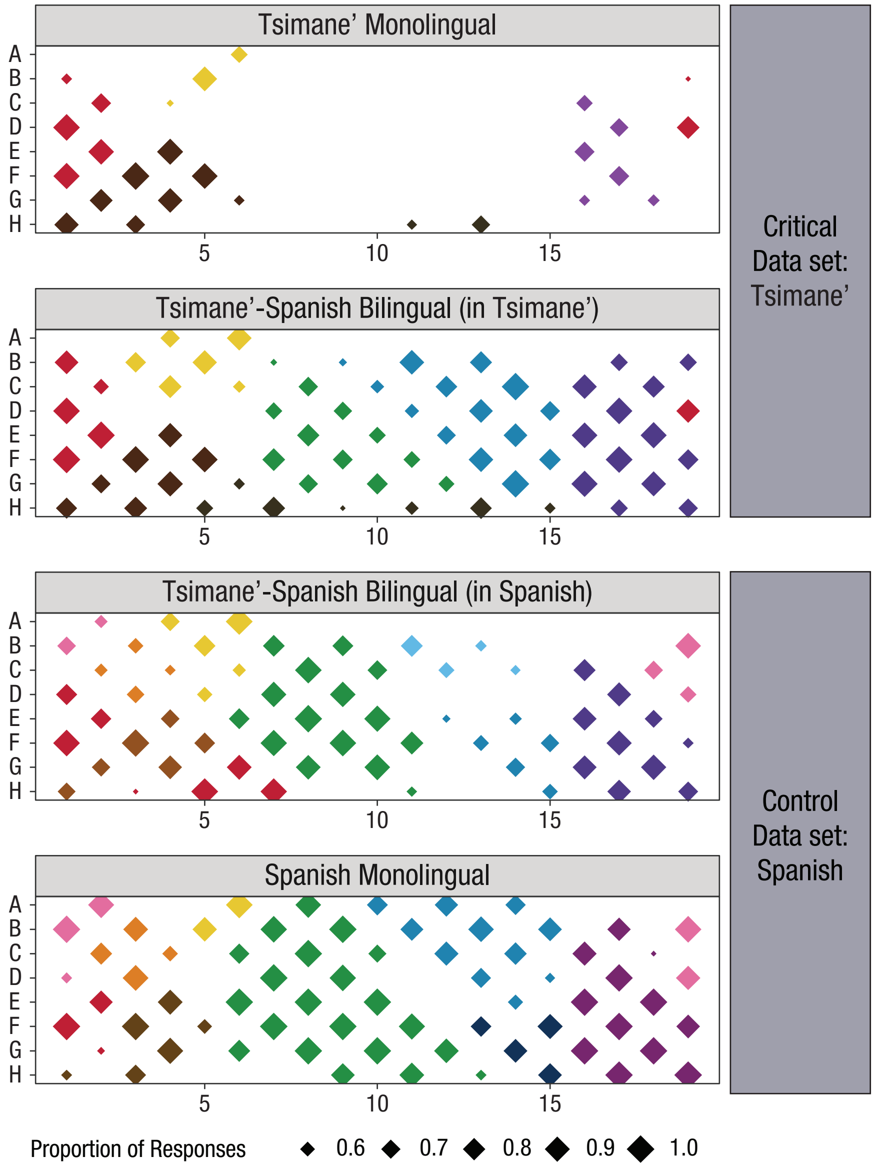

Fig. 2. Chips for which more than half of the population shared a color term. The figure represents the Munsell board (see Fig. S1 in the Supplemental Material for the exact board), in which hue is represented on the *x*-axis and brightness is represented on the *y*-axis. The size of diamonds indicates the proportion of the population that used the modal response. The color of each diamond corresponds to the color of the chip deemed to be the best exemplar of that color term by participants during the focal selection task; for example, F1 was deemed to be the best exemplar of *jäinäs* in Tsimane' and *rojo* in Spanish (~*red* in English) in all four groups (see Table S2 in the Supplemental Material for all focal chips). To see the modal term used for each of the chips, and to view an equivalent figure accessible to color-blind populations, see Figure S4 in the Supplemental Material.

fact, *itsidyeisi/morado* (purple) was not different between any of the four groups. Moreover, between Tsimane' monolinguals and Tsimane' bilinguals, all color terms had different distributions, barring *yụshñus* (blue) and *jäinäs* (red). Between the two languages of the Tsimane'-Spanish bilinguals, none of the distributions were significantly different except *yụshñus/azul* (blue). Table S3 in the Supplemental Material contains the results for all chi-square tests.

These results suggest that Tsimane'-Spanish bilinguals seem to restructure Tsimane' color terms upon learning Tsimane'. Perhaps most notably, the grue space

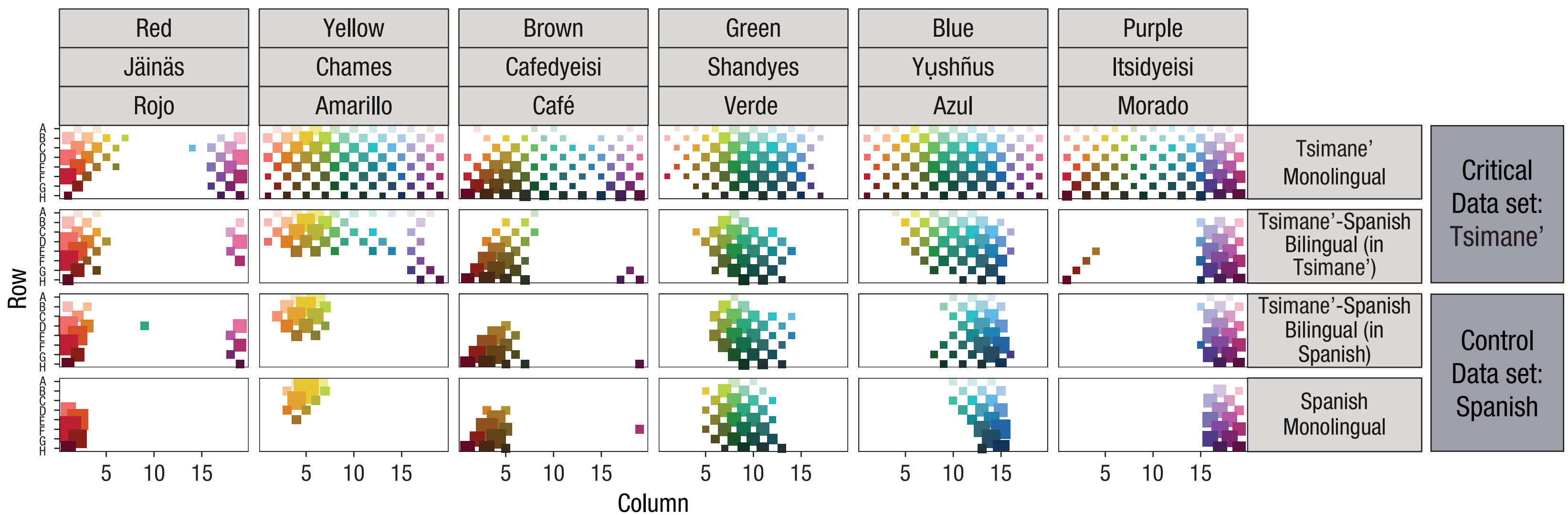

Fig. 3. Comprehension data for the color words *rojo, verde, azul, amarillo, café, morado* (in Spanish) and *jäinäs, shandyes, yuṣhñus, chames, cafedyeisi, itsidyeisi* (in Tsimane') for Tsimane' monolingual, Spanish monolingual, and Tsimane'-Spanish bilingual speakers. Any chip that is colored in the grid is a chip that a participant of that group has chosen for the term in question. The size of the chip is equivalent to the proportion of times that chip was picked for the color term, with all proportions adding up to 1.

is split into a separate *shandyes* (green) and *yu̧shñus* (blue) space by Tsimane'-Spanish bilingual speakers.

The narrowing of Tsimane' color terms from monolinguals to bilinguals

As shown in Figure 3, at times Tsimane' monolingual participants seem to be picking similar chips for two different color terms, as is most evident with the color terms *shandyes* (green) and *yu̧shñus* (blue). Thus, we decided to look next at pairs of color terms that are neighbors in the color space to see the amount of overlap between the terms across the different groups. When we considered Figure 2, we observed that there are eight neighboring pairs of color terms: *jäinäs-chames* (~*rojo-amarillo* in Bolivian Spanish, ~red-yellow in English), *jäinäs-cafedyeisi* (~*rojo-café* in Bolivian Spanish, ~red-brown in English), *cafedyeisi-shandyes* (~*café-verde* in Bolivian Spanish, ~brown-green in English), *chames-cafedyeisi* (~*amarillo-café* in Bolivian Spanish, ~yellow-brown in English), *chames-shandyes* (~*amarillo-verde* in Bolivian Spanish, ~yellow-green in English), *shandyes-yu̧shñus* (~*verde-azul* in Bolivian Spanish, ~green-blue in English), *yu̧shñus-itsidyeisi* (~*azul-morado* in Bolivian Spanish, ~blue-purple in English), *jäinäs-itsidyeisi (~rojo-morado* in Bolivian Spanish, ~red-purple in English). For each of these pairs, we observed the amount of overlap between the chips chosen for the terms in the pair. In Figure 4 we focus on the pairs green-blue, purple-red, and yellow-brown, whereas the rest of pairs can be found in Figure S5.

Similar to the results apparent in Figure 3, Figure 4 shows that the color terms *shandyes* and *yu̧shñus* are essentially perfectly overlapped in the Tsimane' monolingual group, whereas *azul* and *verde* overlap much less in the Spanish monolingual group. There are similar patterns for other color pairs, although not as dramatic as the *shandyes/yu̧shñus* difference. To quantify how overlapping these distributions are, we computed the Kullback–Leibler (KL) divergence using the R package *philentropy* (Hajk-Georg, 2019). This measure gives us a distance between two probability distributions.

Crucially, the KL divergence can be interpreted as the expected excess surprise when using Q as a model when the actual distribution is P. For our purposes, we can use KL divergence over distributions of color chips to ask, what is the expected increase in surprise that arises from using one particular color word (e.g., Tsimane' *shandyes*) to refer to the color space that we know is actually picked out by a different color word (e.g., Tsimane' *yu̧shñus*)? If the two distributions are basically the same, then we would not find any excess surprise by using *yushnes* to refer to the space actually picked out by *shandyes* (i.e., a small KL divergence). But if the two distributions are very different, we would find large excess surprise (i.e., a large KL divergence). Given that this measure is not symmetrical in the two distributions, KL divergences were measured for the alternative order of pairs as well (i.e., KL divergences were calculated for both *shandyes-yu̧shñus* and *yu̧shñus-shandyes*). After removing chips with 0 probability mass for both words, we computed KL using the default epsilon = 0.00001 in the philentropy package to avoid dividing by 0 in the KL calculations. We measured the KL divergence for each of the pairs shown in Figure 4 in each of the language conditions.

For the *shandyes-yu̧shñus* and *verde-azul* (~green-blue) distribution, the KL divergence was smaller for Tsimane' monolinguals (0.10) and largest for Spanish monolinguals (10.65), with Tsimane'-Spanish falling between the two: Their responses in Spanish were closer to those of Spanish monolinguals (6.16), and their responses in Tsimane' were closer to those of Tsimane' monolinguals (1.18). This pattern held true for other neighboring color pairs, such as *chames-cafedyeisi* and *amarillo-café* (~yellow-brown; Tsimane' monolingual = 0.45, Tsimane' bilingual = 1.39, Spanish bilingual = 1.66, Spanish monolingual = 6.28) and *jäinäs-itsidyeisi* and *rojo-morado* (i.e., ~red-purple; Tsimane' monolingual = 1.52, Tsimane' bilingual = 4.58, Spanish bilingual = 12.04, Spanish monolingual = 25.13). The pattern also held for the reverse order of the neighboring color pairs, that is, *yu̧shñus-shandyes* and *azul-verde* (Tsimane' monolingual = 0.24, Tsimane' bilingual = 2.41, Spanish bilingual = 6.12, Spanish monolingual = 11.75), *cafedyeisi-chames* and *café-amarillo* (Tsimane' monolingual = 2.31, Tsimane' bilingual = 9.67, Spanish bilingual = 9.54, Spanish monolingual = 13.69), and *itsidyeisi-jäinäs* and *morado-rojo* (Tsimane' monolingual = 0.34, Tsimane' bilingual = 0.75, Spanish bilingual = 2.19, Spanish monolingual = 4.00; see Fig. 5 for a visual representation of the KL divergences of these color pairs). KL divergences were computed across all 16 color pairs (see Figs. S5 and S6 in the Supplemental Material, as well as Table S5).

Taken together, these results show that Tsimane' color terms become more precise when Tsimane' monolinguals learn Spanish, with their Spanish color terms being close to those of Spanish monolinguals'. But crucially, their Tsimane' terms fall between those of Spanish monolinguals and those of Tsimane' monolinguals.

Discussion

The present results provide evidence using color-naming studies in monolingual and bilingual speakers

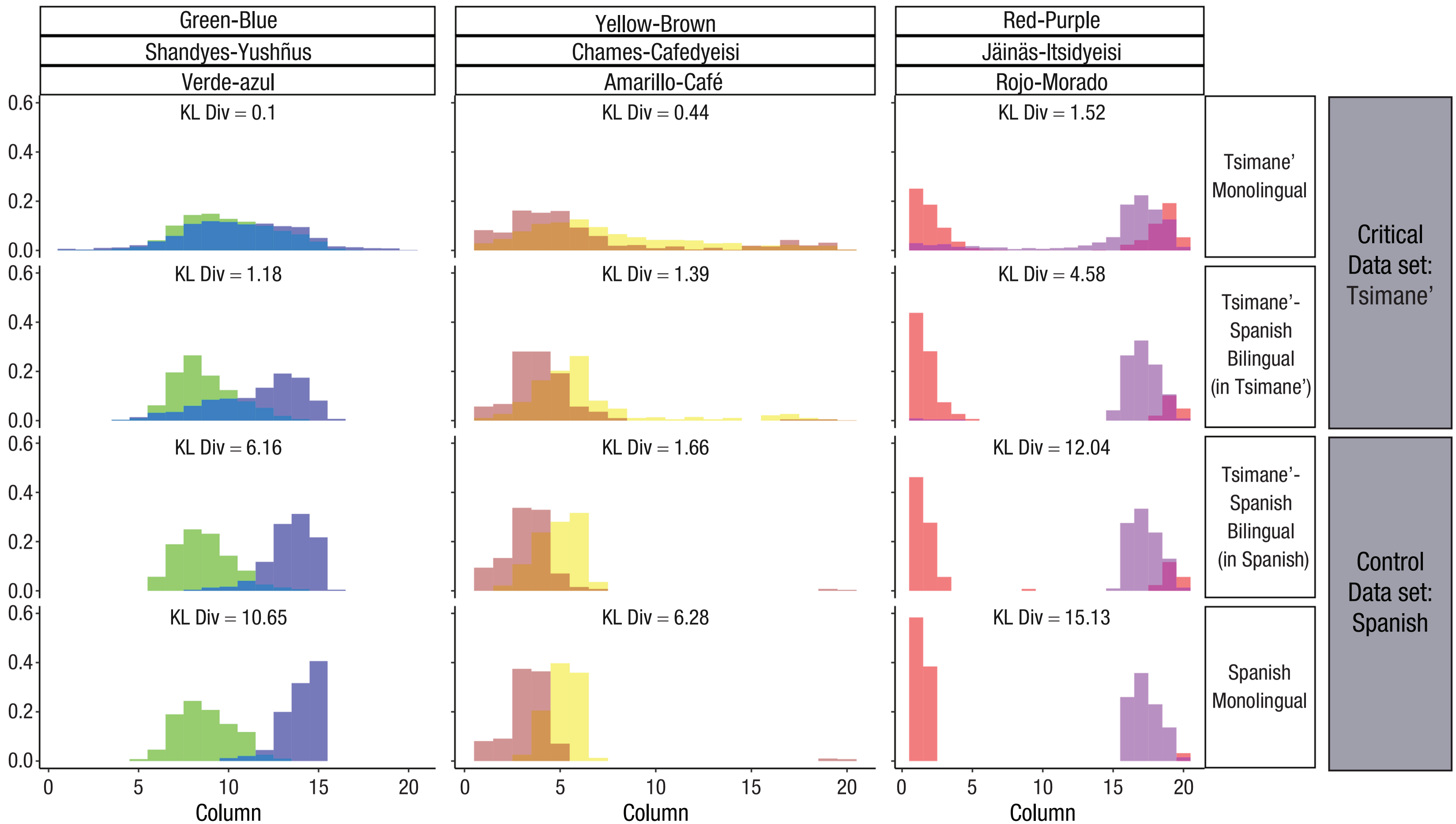

Fig. 4. Normalized histogram of the chips chosen as *shandyes-yușhñus*, *chames-cafedyeisi*, and *jäinäs-itsidyeisi* in Tsimane' and *verde-azul*, *amarillo-café*, and *rojo-morado* in Bolivian Spanish (~blue-green, yellow-brown, and red-purple in English) across the columns on the Munsell array. The presence of a third color indicates an overlap. Columns in the Munsell array represent different hues. Tsimane' monolinguals show the largest overlap between chips chosen for each different neighboring color pair, whereas Spanish monolinguals show the least amount of overlap. The Kullback–Leibler divergence (KL div) for each neighboring color pair is also included.

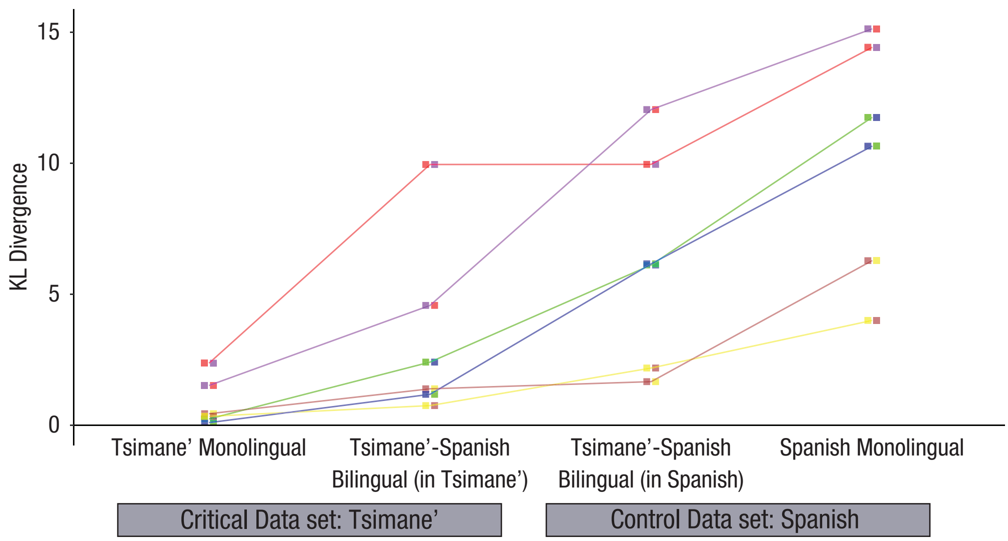

Fig. 5. Average Kullback–Leibler (KL) divergence between the neighboring color-term pairs presented in Figure 4 (green-blue, yellow-brown, red-purple), as well as the reverse of each (i.e., blue-green, brown-yellow, purple-red) across all language groups. See Figure S6 in the Supplemental Material for KL divergences for all neighboring color pairs.

showing that contact with a new language can reshape the concepts in the native language.

Our experiments were designed to distinguish among three possibilities: (a) the Tsimane' color system in Tsimane'-Spanish bilinguals is the same as that of Tsimane' monolinguals; (b) Tsimane'-Spanish speakers borrow Spanish color terms into their Tsimane' color system; or (c) Tsimane'-Spanish speakers restructure the meanings associated with Tsimane' color terms upon learning Spanish. In line with Gibson et al. (2017), we observed that Tsimane' monolingual speakers have higher average surprisal rates than Spanish monolingual speakers. Importantly, Tsimane'-Spanish bilinguals completed the task in Tsimane' with lower average surprisal than their monolingual counterparts, indicating that they do indeed alter their Tsimane' color system by having more consistent color terms. They do not map the Bolivian-Spanish color system into Tsimane', as Tsimane' bilingual speakers do not differentiate between light and dark blue (*celeste* and *azul* in Bolivian Spanish) in Tsimane'. The modal terms reveal that Tsimane' bilingual speakers include two more modal terms than Tsimane' monolinguals (*shandyes* and *yụshñus*), and data from a color-selection task indicate that in Tsimane' monolinguals these two terms are equivalent, forming a green-blue space. However, the restructuring of color terms is not limited to *shandyes-yụshñus*, as the number of chips participants select for all six studied color terms becomes smaller between Tsimane' monolingual and bilingual speakers, and the confusability between all neighboring color pairs diminishes from monolingual to bilingual Tsimane' speakers. Although past literature in contact-induced language change has observed restructuring in a language for morphemes (Owens, 1999), phonemes (Deterding, 2010), and syntax (Håkansson et al., 2002), the present data set is a case of restructuring, with the color-word boundaries being borrowed in Tsimane' from Spanish by Tsimane'-Spanish bilinguals. Understanding how color systems are restructured in the Tsimane'-Spanish bilingual populations also allows one to address whether bilingual subjects integrate semantic representations across their two languages beyond concepts that have translations (e.g., Francis, 2005). The results suggest that bilinguals attempt to integrate conceptual representations of their two languages even when there are no direct translations for the terms in one of the languages.

The present results show larger effects than previously observed in Athanasopoulos (2009), Athanasopoulos et al. (2010, 2011) on restructuring of a native language following acquisition of a second language. It is possible that the larger magnitude of the difference observed here is due to the fact that we tested cultures with large differences in color-term use, and therefore the present results might generalize only to language pairs from vastly different cultures. Both the Whorfian (e.g., Lupyan & Zettersten, 2021) and efficiency-based (e.g., Gibson et al., 2019; Mahowald et al., 2020) approaches predict changes in a native language upon learning a second language. However, a key difference between these approaches is the mechanism behind these changes. In the Whorfian approach, learning a new language that has a different conceptual representation from the native language will alter concepts in the native language of the speaker in all cases. In contrast, the efficiency-based approach predicts that changes will occur only when the speakers need to learn the new conceptual space because of cultural interaction. A limitation of our present study is that all bilinguals tested lived in the Bolivian town of San Borja, which is more industrialized than their Tsimane' communities. Given that more industrialized societies might talk more about color (e.g., Conway et al., 2020; Gibson et al., 2017), industrialization might be driving the increased consistency in Tsimane' color terms in Tsimane'-Spanish bilinguals. That is, it might not be the exposure to the second language that improves efficiency of the color communication system; it might be the interactions in the culture (cf. Daller et al., 2011; Zaslavsky et al., 2022).

The present results have implications for interpreting prior color-naming studies, many of which have relied on bilingual speakers and implicitly assumed that the use of color terms within a language is unaffected by having a second language (e.g., Berlin & Kay, 1969; Wnuk et al., 2022; Zaslavsky et al., 2022). An influential study by Berlin and Kay (1969) proposed a universal pattern in which color terms evolve (Berlin & Kay, 1969). The participants in the study were all bilingual speakers who mostly lived in the United States and also spoke English (some bilinguals in Mexico spoke Spanish). The present results showing how color concepts can restructure following contact with a new language complicates claims of universality in these data, because any similarities in how colors are named could result from the restructuring process rather than an innate propensity to categorize the colors in the same way across languages. Subsequently, Kay and his colleagues collected a large amount of data from monolingual speakers in the World Color Survey. The resulting data showed greater variability among languages than suggested by the work using bilingual speakers (Kay & Maffi, 1999), consistent with the possibility that some of the original results may have been driven by having bilingual participants. Similarly, the restructuring of concepts following contact with a new language may be confounded in data showing the evolution of the Nafraana color-naming system from three color words in 1978 to nine in 2018 (Zaslavsky et al., 2022). By 2018, many speakers of Nafraana also spoke English. Given the present results, it is plausible that bilingualism, instead of (or in addition to) a pressure for efficiency, led to an increase in color terms in the Nafraana. The present results serve as a caution for claims of cross-cultural universality when data are obtained in bilingual speakers.

In summary, in the present study we observed how Tsimane' terms become more consistent and precise when Spanish is acquired by the speaker. More broadly, these results show that contact with a new language can alter concepts in the native language.

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Saima Malik-Moraleda: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft.

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Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/09567976231199742

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