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The origins of the shape bias: Evidence from the Tsimane'.

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Abstract

In the US, children often generalize the meaning of new words by assuming that objects with the same shape have the same name. We propose that this shape bias is influenced by children's exposure to objects of different categories (artifacts and natural kinds), and language to talk about them. We present a cross-cultural study between English speakers in the US and Tsimane' speakers in the Bolivian Amazon. We found that US children and adults were more likely to generalize novel labels by shape rather than by material or color, relative to Tsimane' participants. Critically, Tsimane' children and adults systematically avoided generalizing labels to objects that shared no common features with the novel referent. Our results provide initial evidence that the relative exposure to objects of different kinds and language to talk about them can lead to cross-cultural differences on object name learning.

Introduction

Understanding what new words refer to is a central problem when learning a language. If a speaker of an unfamiliar language points to a rabbit and says "gavagai," how can we tell if gavagai means animal, mammal, dinner, rabbit, or undetached rabbit parts (Quine, 1960)? Studies conducted in the US suggest that children learning English solve part of this challenge by assuming that objects with the same shape have the same name (Landau, Smith, & Jones, 1988). This *shape bias* is believed to be learned (Samuelson & Smith, 1999; Gershkoff-Stowe & Smith, 2004) and reflects children's understanding that shape often reveals category boundaries (Bloom, 2000; Diesendruck & Bloom, 2003; Rosch et al., 1976). The shape bias appears to be so useful that 17-month-olds who acquire it through an early intervention (as the shape bias is usually acquired at around age three) know more object names two months later, when compared to children in a control group (Smith et. al., 2002). Nonetheless, these studies possibly lack geographical, ethnic, and socio-economical variability, and their results should be interpreted accordingly.

Critically, the shape bias is not useful for all nouns and it must be used strategically. In particular, the shape bias is powerful for artifacts, which are often made with a function that determines their shape, but not their material or color (e.g., cups, toothbrushes, pens and books have stable shapes but often show variable material and color). By contrast, a shape bias is less useful for at least three other categories that people commonly encounter: (i) objects of natural kinds, where material and color can be equally or more important than shape (e.g., plants and plant parts like leaves, trees, and flowers; inert objects like rocks and sticks; and edible roots and fruits like yuca and soursop); (ii) animates, where both shape and texture are important (e.g., consider the intuitive pattern-based distinction between a zebra and a horse); and (iii) substances, where shape is entirely irrelevant (e.g., sand and water; Rosch et al., 1976). Consistent with this, children in the US are more likely to show a shape bias when the referent is an object (rather than a substance; Li, Dunham, & Carey, 2009), when the object is introduced as an artifact (as opposed to an animate object; Booth, Waxman, & Huang, 2005; Booth & Waxman, 2002), and when the object has a complex shape (which may provide further evidence that it is an artifact; Li, Dunham, & Carey, 2009).

Given that the shape bias is acquired through exposure and talk about shape-based categories (Smith et. al., 2002), and given that its use can be disadvantageous when applied to natural kinds, animates, and substances, we hypothesized that the strength of this bias is partially driven by environmental factors that vary based on where children grow up (Everett, 2005; Henrich, Heine, & Norenzayan, 2010; Mazuka & Friedman, 2000). Children raised in highly industrialized societies might be unique in human history in their extreme exposure to artifacts and shape-bounded categories. By contrast, children in less industrialized societies have a higher exposure to natural kinds and hence increased exposure to words whose boundaries are not marked by shape alone. We therefore hypothesized that, when encountering novel objects, children from highly industrialized societies would be more likely to deploy a shape bias relative to children from less industrialized societies.

Previous work on shape-bias variation

Previous work has documented that the strength of the shape bias varies across cultures: Speakers of Mandarin, Japanese, and Yucatec-Mayan show a weaker shape bias compared to English speakers (Lucy & Gaskins, 2001; Li, Dunham, & Carey, 2009; Imai & Mazuka, 2003). These differences were initially interpreted as evidence that language influences thought. At the heart of this idea was the observation that English syntax divides nouns into two categories: *count nouns* (objects where shape is important) and *mass nouns* (substances where shape is irrelevant). This distinction is marked through a variety of linguistic mechanisms that include pluralization (only count nouns can be pluralized; e.g., "cows" is valid but "muds" is not), countability (only count nouns can be combined with numerals; e.g., "two cows" is valid but "two muds" is not), and determiner use (mass nouns cannot take indefinite determiners; e.g., "a cow" is valid but "a mud" is not; see Fieder, Nickels, Biedermann, 2014 for review). According to some proposals, learning a language with a count/mass distinction (like English) yields a tendency to distinguish objects from substances, which then supports the acquisition and selective use of a shape bias for objects. Under this account, speakers of Japanese, Yucatec Mayan, and Mandarin show a weaker or absent shape bias because their languages lack a count/mass distinction.

This interpretation, which falls in the domain of *linguistic relativity* (the broad array of potential linguistic effects on non-linguistic cognition; Quine 1960, 1969; Whorf 1956; Lucy & Gaskins, 2001; see Imai & Mazuka, 2003 for review), has been challenged on the basis of three observations. First, this account assumes that the linguistic count/mass distinction maps onto the conceptual object/substance distinction, but this is not always the case (e.g., *furniture* and *jewelry* follow mass syntax in English but people nonetheless conceptualize them as objects; Barner, et al., 2010; Barner & Snedeker, 2005). Second, English and Mandarin speakers show an identical object/substance distinction in non-linguistic tasks, suggesting a linguistic count/mass distinction is not necessary for a conceptual object/substance distinction (Li, Dunham, & Carey, 2009). Finally, English-Mandarin bilingual speakers show a shape bias when the task is presented in English but not when it is presented in Mandarin (Barner, Inagaki, & Li, 2009), suggesting that linguistic framing rather than non-linguistic representations modulate these effects. Critically, this type of linguistic relativity proposal extends beyond the count/mass distinction and includes hypotheses about the influence of other linguistic categories (such as noun classes and classifiers) on other semantic dimensions (see Everett, 2013 for a review). The reviewed challenges should therefore be interpreted as an isolated difficulty in explaining shape bias variation in terms of the count/mass linguistic distinction, and not as a general challenge of linguistic relativity.

Given these challenges, the documented cross-linguistic variability in the shape bias is now commonly believed to reflect *lexical statistics* (which can be considered to fall under the larger umbrella of linguistic relativity). Under this view, because Mandarin, Japanese, and Yucatec-Mayan use the same syntax for objects and substances, listeners cannot determine if the label applies to the object or to the substance, preventing them from applying a shape bias (Barner, Inagaki, & Li, 2009; Barner, Li, & Snedeker, 2010; Barner & Snedeker, 2004). By contrast, English syntax helps people determine when to use shape bias. Even when using syntactic constructions that are technically ambiguous, people can determine whether the referent is likely to be an object or a substance based on how often the chosen construction is used to refer to different objects (e.g., the construction "the *dax*" does not reveal whether *dax* is an object or a substance, but listeners might still infer that it is an object because this construction is more commonly used when talking about objects). Critically, the lexical statistics hypothesis explains variability in shape bias as an effect of pragmatics in language, rather than an effect of language on thought.

Our proposal is consistent with the *lexical statistics* hypothesis, but our focus is different. Work on the lexical statistics hypothesis has focused on the statistical association between linguistic constructions and referent types (e.g., the construction "the X" is typically used when talking about objects, not substances). Our hypothesis extends this work by proposing that the shape bias is not only modulated by how people talk about different categories, but also by environmental statistics that affect what categories people talk about in the first place.

The current work

Here we present a first test of our hypothesis, exploring the strength of the shape bias in two groups that vary in their level of industrialization: people living in the US, and the Tsimane' living in the Bolivian Amazon. The Tsimane' are an indigenous group of horticulturalists living in the Bolivian Amazon (Huanca, 2008), that have less contact with market-integrated communities (relative to children typically tested in the US; Minkin & Reyes-García, 2017; Masferrer-Dodas et al., 2012; Godoy et al., 2007). The Tsimane' exhibit a variety of cultural differences relative to people from industrialized societies. For instance, the acquisition of number words shows a different timeline relative to children in the US (Piantadosi, et al., 2014; Jara-Ettinger, et al., 2017); their color vocabulary differs from color vocabulary that is associated in cultures where manufactured goods are pervasive (Gibson, et al., 2017; Conway, et al., 2020); and their subjective preference for consonance in music differs from people exposed to Western music (McDermott, et al., 2016).

More specific to our work, the Tsimane' might differ from people living in the US in three ways. First, the environmental distribution of objects that are categorized by shape might differ across populations (relative to objects that are categorized by other dimensions such as material, or combinations of shape, material, and color). Second, the prevalence of words in the lexicon that divide the world based on shape might differ across languages (relative to words that divide the world based on other features or combinations of features). Finally, the habits and customs leading members to engage in action or talk that highlight shape-based categories might differ across cultures. These potential differences between people in the US and Tsimane' create a useful comparison point to conduct an initial test of our hypothesis. We return to theses potential differences in the discussion.

Here we compared the strength of the shape bias in Tsimane' and US participants. As noted above, past research suggests that the shape bias is modulated by a wide variety of factors, including shape complexity, linguistic framing, conceptual information, and even learners' access to tactile information (Barner, et al., 2010; Barner & Snedeker, 2004; Booth, et al., 2005; Booth & Waxman, 2002; Li et al., 2009; Lucy, 1992). Therefore, a complete comparison of the shape bias would require exploring the full range of ways in which people encounter novel objects. Here, as a first step, we focused on a simple event and worked to ensure that any documented effects were stable, replicable, and not due to task misunderstanding. Throughout, we used novel solid objects with simple and clear shapes (based on the stimuli from Yee, Jones, & Smith, 2012; extended to include additional variability in materials and colors; Tables 1-2;

Figure 1). In addition, we used constructions designed to name the object ('a' and 'yiris/yirity' which are more likely to modify count nouns in English and Tsimane', respectively; see SI). Our studies used a single trial per participant, as opposed to repeated trials, as is typically done in studies with US children (e.g., Landau, et al., 1988). This was to avoid potential order effects, which may play a bigger role in populations less accustomed to interactions like the ones that experimental testing requires.

In Experiments 1 and 2 we first show that our stimuli elicit a shape bias in US children but not in Tsimane' children. To ensure that our results are not due to task miscomprehension, Experiment 3 tests children's preference among shape matches, material matches, and distractor objects, and Experiment 4 tests children's preference among shape matches, color matches, and distractor objects. In both experiments, we find no preference for shape-matched objects, but a significant dis-preference for distractor objects. Finally, to explore if our stimuli elicit a shape bias in older participants, Experiments 5-7 test US and Tsimane' adults. We find that our stimuli elicit a shape bias in US but not in Tsimane' adults.

Experiments

Data collection with the Tsimane' was performed through daily trips to Tsimane' communities near San Borja, Bolivia, in collaboration with the *Centro Boliviano de Investigación y de Desarrollo Socio Integral* (CBIDSI). Data was collected from the following Tsimane' communities: Arenales, Campo Bello, Cara Cara, La Cruz, Las Minas, Limonsito, Puerto Codo, Puerto Mendez, San Gregorio, and Uvasichi. All data with Tsimane' children was collected in July 2013, and data with Tsimane' adults was collected in July 2014. Data with US children and adults was collected between September and November of 2013. We aimed to have a sample size of at least 30 participants per experiment. However, Tsimane' children and adults interested in participating once we had surpassed the target sample size were allowed to participate, as agreed with the local Tsimane' authorities. In the US, the sample size in children was matched to exactly 30 participants, and the sample size with adults was set to be large enough to allow us to fully counterbalance all aspects of experimental design. All research was approved by MIT's COUHES 1806394492 "Investigations of universal cognitive abilities in the Tsimane'" and by the Gran Consejo Tsimane'.

Participants.

30 US children (mean age = 5.64; range=3.86-9; SD=1.38) were recruited in Experiment 1. 37 Tsimane' children (mean age = 5.65; range=3-8; SD=1.34) were recruited in Experiment 2. 42 Tsimane' children (mean age = 6.66; range=3-11; SD=1.92) were recruited in Experiment 3. 30 Tsimane' children (mean age = 5.65; range=3-8; SD=1.34) were recruited in Experiment 4. All Tsimane' children were recruited and tested in their communities. Due to an agreement with Tsimane' authorities, and because of concerns that participants would provide inaccurate ages if we restricted the age range, we recruited any child interested in participating. Further, we only obtained each participant's range as integers because the Tsimane' do not typically track their child's age with higher precision. Ages were obtained from each participant's parent.

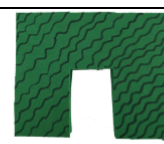
US children were recruited and tested at an urban museum in Boston and the age range was selected to match that of our Tsimane' sample (rounded to years). No child participated in more than one experiment and each experiment's analysis was performed once data collection was complete.

144 US adults (mean age = 30.02; range=19-72; SD=9.06) were recruited in Experiment 5. 39 Tsimane' adults (mean age = 30.26; range=16-80; SD=13.98) were recruited in Experiment 6. 41 Tsimane' adults (mean age = 31.32; range=18-73; SD=14.2) were recruited in Experiment 7. US adults were recruited using Amazon's Mechanical Turk platform and tested online. Tsimane' adults were recruited and tested in their communities.

Tsimane'-Spanish bilinguals are uncommon and typically live in the Spanish-speaking town of San Borja. One notable exception is community school teachers, who were often bilingual. Overall, Tsimane' adult participants reported an average of 2.78 years of formal schooling (sd=2.16). As part of their demographics, we conducted a simple survey asking if they recognized the meaning of 11 simple common Spanish words. Participants on average recognized 6.85 words (sd=2.36), and none recognized all eleven words, even though they were selected as very common words of use in Spanish for Tsimane' speakers, like "house," "egg," "dog," and "snake" (see Supplemental Materials for details). To our knowledge, schools were not teaching Spanish to children at the time we ran this study (although that has recently changed).

Stimuli.

Stimuli consisted of solid objects that varied in shape, color, and material, shown in Table 1 (based on the stimuli from Yee, Jones, & Smith, 2012). Table 2 shows the materials used in our task. Each experiment consisted of three example objects and three extension objects (with the exception of Experiment 7, which had four extension objects). Each participant saw only one example object (counterbalanced across participants) and all extension objects (see Figure 1 for each object's role as exemplar or extension). All experiments used physical objects, except Experiment 5 which used photographs of the objects (Table 1), as it was conducted online.

				
Blue yarn arch	Red yarn arch	Red foam arch	Green foam arch	Yellow fabric arch
				
Blue crepe-paper lamp	Red foam lamp	Green fabric lamp	Yellow foam lamp	
				
Blue fabric snowman	Red crepe-paper snowman	Yellow yarn snowman		

Green polka-dot disc

Table 1. Pictures of stimuli used in our Experiments. See Figure 1 for how stimuli associated with each experiment.

Each experiment had three conditions, determined by which of the three possible example objects the participant saw (Figure 1). The extension objects were designed so that each object played a different role (as a shape, material, or color match, or as a distractor object) depending on the participant's condition (i.e., depending on the object that the participant saw). For example, when the arch-like object was used as the example object in Experiment 3, the first, second, and third extension objects served as the shape match, the material match, and the distractor object, respectively. By contrast, when the lamp-shaped object was used as the example object, the same three extension objects now served as the material match, the distractor object, and the shape match, respectively. Thus, this design enabled us to avoid potential confounds due to some objects being more visually salient than others.

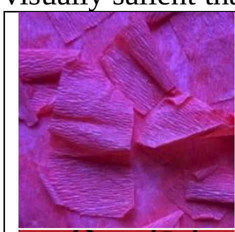
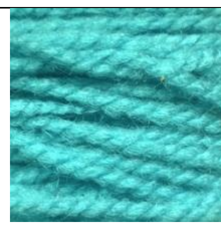
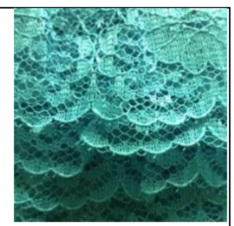
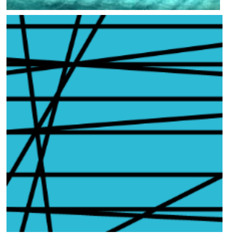
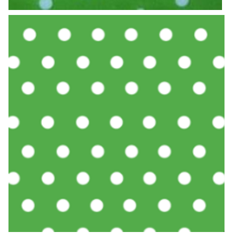
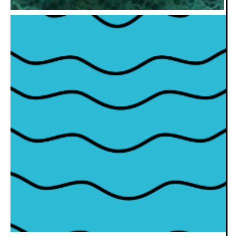
				
				
Crepe paper	Smooth patterned craft foam	Yarn	Smooth plastic with polka dots	Layered fabric

Table 2. Materials used in our task. The top row shows zoomed-in photographs of the materials, the second row shows the abstract visualizations used to show the Experiment logic in Figure 1, and the bottom row describes each material.

Procedure.

All experiments were one-shot learning trials and each participant completed one trial only. Although each trial only required one label, we used three different possible labels, randomized across participants. In the experiments with US participants, the example object was called a "koba", "dax", or "fep". In the experiments with Tsimane' participants, object names were phonetically modified by our interpreters so they would sound like plausible Tsimane' words (pronounced as [koba], [dak^h], and [fep^h] in line with Tsimane' phonology). These words were selected by our interpreters from a longer list (based on Horst & Hout, 2016) to ensure they could be modified to sound like Tsimane' words.

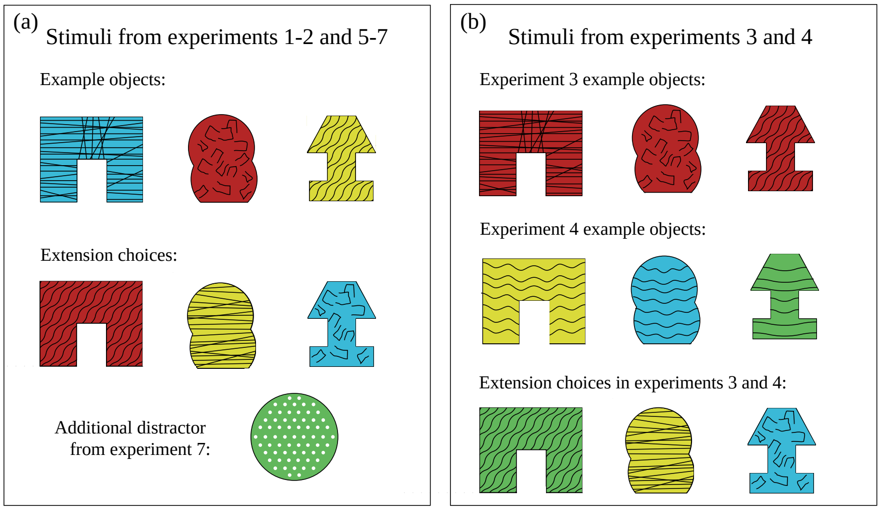


Figure 1: Stimuli used in Experiments 1 though 7. In each experiment participants saw one of the three example objects (counterbalanced across participants), learned its name, and were then asked to generalize the name to one of the three extension objects. Experiments 1, 2, 5, 6, and 7 all used the same stimuli except that Experiment 7 had an additional distractor object. Experiments 3 and 4 used the same extension choices but different example objects. The stimuli were designed such that, with the exception of the distractor object in Experiment 7, each object's role (as a shape, color, material match, or as a distractor) varies depending on which example object is shown. See SI for detailed information.

Past research investigating the shape bias cross-linguistically has generally used neutral syntax like "the dax" (Li, et al., 2009; Barner, et al., Li, 2009). To avoid an alternative explanation where a lack of a shape bias could be explained by appealing to ambiguity in the referent (i.e., the Tsimane' may have a shape bias, but not show it if they believe that the novel word refers to the object's material), our novel labels were directly modified by *yiris/yirity* (gendered "one"). In Tsimane', *yiris/yirity* must directly precede nouns, and can only precede adjectives when there is also a noun to follow. Thus, including the numeral *yiris/yirity* directly before the novel word revealed that the referent identified the entire object and not a property of said object (see SI for relevant linguistic acceptability data).

In Experiment 1 (US children), the experimenter placed the exemplar object on a flat surface so that participants could see that the object was rigid. The experimenter then said "This is a(n) x" (see above for naming conditions). Next, while leaving the exemplar in sight, the experimenter opened a box with three new objects: one shape-matched object, one material-matched object, and color-matched object, and asked "can you point to the x?"[1] Children's answers were then recorded. The position of the three novel objects was randomized across participants in all tasks and participants were not allowed to grab or manipulate the objects.

Experiments 2-4 (Tsimane' children) were identical to Experiment 1 with the

[1] Note that although we used an ambiguous construction in the extension question of the English task, the object's name was introduced using an unambiguous construction that revealed the label referred to an object. Moreover, both US children and adults showed a robust shape bias, and only the absence of a shape bias can be explained by the absence of a proper grammatical construction.

difference that they were run in Tsimane'. After showing the experimenter showed the example object, the interpreter explained "Mu'ca yirity x" ("This is a(n) x").[2] Next, the experimenter presented the three additional objects and the interpreter asked "Ju'ñity acaty yoctyi x" ("which one is also a(n) x?"). In Experiment 2, the three possible extension choices were a shape match, a color match, and a material match (Figure 1). In Experiment 3, the three possible extension choices were a shape match, a material match, or a distractor object (the role of each extension object varied depending on which exemplar was shown, therefore counterbalancing context-independent biases for each object; see Figure 1 and Stimuli section). In Experiment 4, the three possible extension choices were a shape match, a color match, and a distractor object (randomizing the role of each extension object as in Experiment 3; see Figure 1). Thus, Experiment 2 enabled us to compare Tsimane' child data directly with US child data, while Experiments 3 and 4 served as conceptual replications, allowing us to also ensure that Tsimane' children understood the task and were not answering randomly.

Experiment 5 (US adults) was similar to Experiment 1 with the difference that it was run online using Amazon's Mechanical Turk service. Participants in Experiment 5 saw a single screen where the top said "This is a(n) x" along with a picture of the object. Below, the text read "One of these is also a(n) x" along with three pictures of the three possible extension choices. The text below read "Which one is the other x?" Participants were allowed to select one of the three objects. To ensure that participants were attending to the task, we also asked participants what each object shared in common with the original object. These questions were only included to motivate participants to look at the images carefully, but they were not used as exclusion criteria.

Experiment 6 was identical to Experiment 2, with the exception that it was run with Tsimane' adults. In Experiment 7 we replicated the findings from Experiment 6 with the difference that we included a fourth distractor object (see Figure 1) to ensure participants were not responding randomly. All data and analyses files are available at: https://osf.io/egc9y/

Results

We begin by presenting the descriptive statistics behind children and adults' performance across tasks, shown in Figure 2, and then turn to our main analyses.

Overall results

Experiments 1-4. In Experiment 1 60% of US children preferred the shape match, 33.33% the material match, and 6.66% the color match (Figure 2). By contrast, Tsimane' children in Experiment 2 showed a weaker preference for the shape match (32.43% of choices), relative to the material (43.24% of choices), or color (24.32% of choices) match.

Experiment 3 contrasted shape versus material in Tsimane' children. Overall,

[2] Interpreters were trained beforehand on the critical aspects of the task but were given some freedom to deviate from the script as necessary because many children are shy (e.g., by adding "it's okay"). A small proportion of the tasks were audio-taped and back-translated to Spanish to ensure that the experiment was run correctly. In 87.5% (n=14) of the tapes the translator directly modified the nonce word by a number word. The translators used the definite article *mu'* in the remaining two cases (e.g., "this is *the* dax"). The authors were also taught to recognize the number word and ensured that the interpreters used the appropriate utterance during the study.

64.24% of children generalized the label based on material, 20.57% based on shape, and 7.14% chose the distractor object. Experiment 4 contrasted shape versus color in Tsimane' children. 56.67% of children generalized the label by color, 33.33% based on shape, and 10% chose the distractor object.

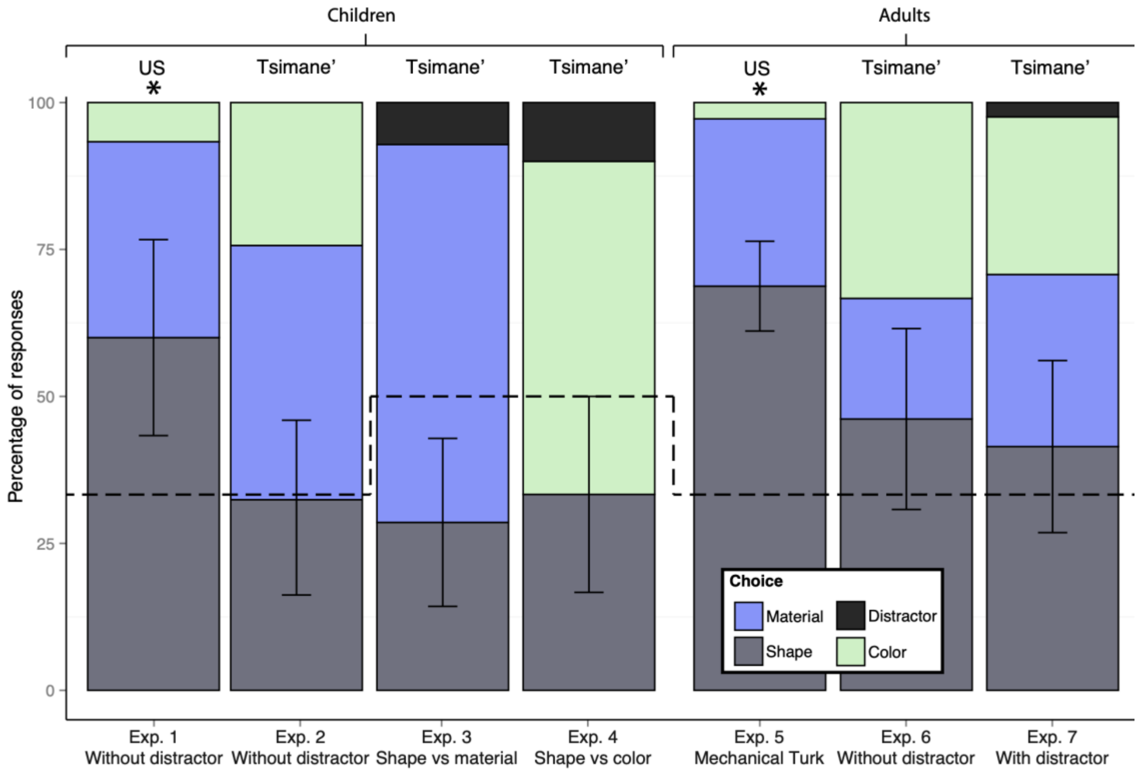


Figure 2: Results from Experiments 1-7. The x-axis shows each experiment and the y-axis shows the percentage of responses across all choices. Vertical lines show 95% confidence intervals computed through a non-parametric bootstrap. The dotted line shows expected chance performance excluding distractor objects. That is, the dotted line shows the number of shape-matches expected to be found in a group with no shape bias but with a dis-preference for distractor objects.

Experiments 5-7. In Experiment 5, the majority of US adults preferred to generalize the object label by shape (68.75% of choices) over material (28.48% of choices) and color (2.77% of choices). By contrast, Tsimane' adults in Experiment 6 showed a comparable preference for the shape (46.15% of choices), material (20.51% of choices), and color (33.33% of choices) matches. In Experiment 7, Tsimane' adults did not show a strong preference for shape (41.46%), material (29.27%), or color (26.83%) matches, but dis-preferred the distractor object (2.44% of choices; n=1 participant).

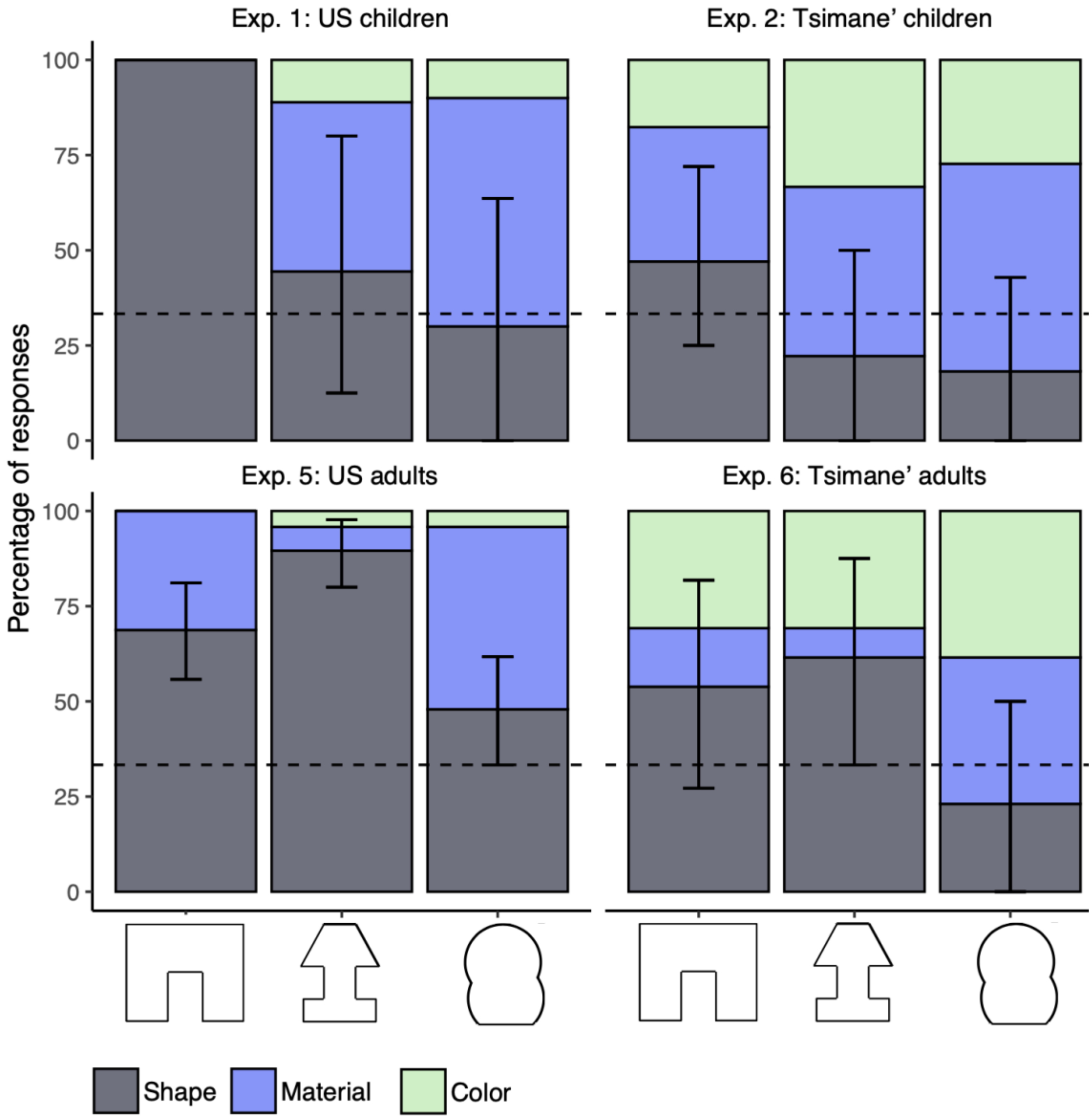


Figure 3: Results from Experiments 1, 2, 5, and 6 as a function of exemplar. The x-axis shows each exemplar shape and the y-axis shows the percentage of responses across all choices. Vertical lines show 95% confidence intervals computed through a non-parametric bootstrap. The dotted line shows expected chance performance.

Main analysis. To test people's propensity to generalize a novel label by shape, we combined the data from Experiments 1 (US children), 2 (Tsimane' children), 5 (US adults), 6, and 7 (Tsimane' adults; excluding the one participant in Experiment 7 who selected the distractor objects). We then ran a logistic mixed-effects model predicting participant's preference for the shape-match object (with baseline probability p=1/3) with population (US or Tsimane' participants, dummy coded) and age group (children or adults, dummy coded) as independent variables. A population by age interaction effect was not included as determined by nested model comparison. To control for the role of exemplar (Figure 3), our regression included random intercepts for each Experiment, random intercepts for exemplar object, random slopes for population as a function of exemplar, and random slopes for age group as a function of exemplar. This model found no significant shape bias for Tsimane' participants (β=0.41; *p*=0.18 for the intercept), but showed that US participants were significantly more likely to generalize the label by shape (β=1.22; *p*<0.01) and no difference across age groups (β=-0.62; *p*=0.34; see Supplemental text for full regression table).

Experiments 3 and 4 serve to ensure that Tsimane' children's responses in Experiment 2 did not reflect random choices (due to potential task misunderstanding). If children did not understand what was requested from them, we reasoned that children would continue to choose all three extension objects even when one of them shared no shape, material, or color to the exemplar. To test this, we combined the data from Experiments 3 and 4 and ran a logistic mixed-effects model predicting participant's preference for the distractor object (with baseline probability p=1/3) with random intercepts by exemplar object and by Experiment. This model revealed a significant dis-preference for the distractor object (β=-1.71; *p*<0.001), confirming that Tsimane' children were not simply generalizing the novel object label by chance.

Finally, the results from Figure 2 suggest that Tsimane' participants may have a reduced preference for material matches as a function of age (Comparing Experiment 2, to Experiments 6 and 7).[3] To test this, we combined data from these three Experiments and tested participant's preference for the material match as a function of age group (with baseline probability p=1/3), with random intercepts by exemplar object, random slopes for age groups by Exemplar, and random intercepts by Experiment. This analysis revealed a marginal decrease in material preferences (β=0.81; *p*=0.055). We return to this point in the discussion.

Discussion

Here we sought to evaluate the idea that people's propensity to generalize object labels by shape is influenced by the distribution of categories that people encounter and talk about in their daily life. In particular, we hypothesized that children from highly industrialized societies would be more likely to deploy a shape bias relative to children from less industrialized societies. In a one-shot word-generalization task using novel objects, we found that participants from the US showed a stronger propensity to generalize objects labels on shape relative to Tsimane' children and adults.

Our findings are consistent with the idea that humans generalize object labels based on the features that they believe will be diagnostic of the object's category (Bloom, 2000; Diesendruck & Bloom, 2003; Rosch et al., 1976). Our hypothesis expands on this idea, proposing that exposure and talk about different categories affects how people choose to generalize novel words. This idea is consistent with computational models showing that the shape bias can be explained as a learned generalization of correlations between category boundaries and shape (Samuelson, 2002; Colunga & Smith, 2005; Kemp et al., 2007).

Interestingly, our results suggested that, among the Tsimane', children were more likely to generalize labels based on material relative to adults. Note however, that this effect was small, and we do not know it reflected a preference for material or a dis-

[3] We thank an anonymous reviewer for the suggestion to analyze material preferences in the Tsimane'.

preference for color or shape. Critically, this does not imply that the Tsimane' never generalize labels by shape. The Tsimane' regularly interact with artifacts such as cooking utensils, canoes, machetes, and shotguns. To our knowledge, all of these categories are similar to English ones, and they are construed on the basis of function, which correlates with shape. In addition, our study pitted shape, material, and color against each other. In more realistic situations, categories depend on a combination of features. For instance, the Tsimane' word for fishing net (*saji'*) might generalize by both shape and texture, and the words for ripe and unripe banana (*pe're* and *p̂ujsi'*; Gill, 1993; Lourdes Suárez, 2007) might generalize by both shape and color. We thus see our results as showing a cross-cultural effect on people's propensity to generalize by shape alone, and not as an absolute presence or absence of a shape bias.

Study limitations

While our study shows a difference in shape-bias across populations, our results have several limitations. First, people encounter novel objects in a variety of contexts and the way in which they generalize labels arguably depends on additional conceptual information (e.g., does the speaker reveal that the object is an artifact? Booth, et al., 2005; Booth & Waxman, 2002), linguistic framing (Barner, et al., 2010; Li et al., 2009), and availability of tactile information (Lucy, 1992). Therefore, we do not know the extent to which our results would change under different objects or contexts. In particular, the Tsimane' might exhibit a stronger shape bias when presented with objects that are unambiguously artifacts, or when they have an opportunity to interact with the object before deciding how to generalize its label. In addition, our study used novel objects with unnatural shapes, materials, and colors, and we do not know how the Tsimane' perceived the relative novelty of each property. Nonetheless, all materials were obtained in San Borja, the nearest market-integrated town, and we believe it is likely that the Tsimane' had encountered all of these materials before: fabric is pervasive in Tsimane' communities, paper can be found in Tsimane' schools (although not necessarily crepe paper), and there is documentation of yarn being provided as a gift for participation in studies (Martin, Blackwell, Kaplan, & Gurven; 2019).

Conversely, our study with US adults was conducted online, and this method may have elicited a stronger shape bias, possibly due to reduced salience in materials, and increased variability in color across participants' monitors. However, it is useful to note that multiple studies have established a shape bias in US adults in a variety of methods that include interaction with real objects (Li, et al., 2009) and presentations on screens (Vlach, 2016). Therefore, while our results are consistent with previous work documenting a shape bias in US adults, the comparison between US and Tsimane' participants should be interpreted cautiously, as it is possible that seeing real-world objects leads to different generalization biases than seeing objects on a screen. This possibility would be particularly interesting, given the rise of screen-based learning. Recent research indeed suggests that toddlers are less likely to learn the word of a novel object when it is presented via a screen (Tsuji, et al., 2020).

Finally, our study has a linguistic limitation. Our experiments with Tsimane' participants directly modified the novel word with a number word (*yiris/yirity*), with the goal of revealing that the label applied to the entire object, rather than to a property of the object. In support of this possibility, our linguistic acceptability tasks suggested that, in Tsimane', substances are less likely to be modifiable directly by number words. In this linguistic task, however, many participants still found it acceptable for number words to modify substances. Moreover, this acceptability task used non-shapeable substances like water, sand, and mud (see SI for full details). It is possible that Tsimane' participants are even more likely to allow number words to modify shapeable substances (like clay or yarn), which leads to the construal of a material-based object (see also Samuelson, et al.; 2008). This opens the possibility that linguistic differences could have increased the Tsimane's willingness to generalize labels by material, helping explain Tsimane' increased preference for material matches.

Open questions

Our work also leaves a major open question for future work. What mechanisms underlie the shape bias difference that we found here? The first potential mechanism is environmental: the availability of artifacts relative to natural kinds across populations may underlie people's propensity to treat shape as a feature that dominantly guides category boundaries. The second potential mechanism is linguistic: different languages may have a different distribution of shape-bounded words relative to words that identify categories that are marked by other features (or a combination of features). The third mechanism is cultural: a group's practices might bias conversation towards different categories (Perry & Samuelson, 2011; Perry, et al., 2010). Naturally, these three mechanisms are deeply related. People's environment likely affects what people talk about and shapes their language's lexicon. In addition, it is likely that multiple of these forces are at play in parallel and together shape how people generalize object labels. Nonetheless, these mechanisms are all dissociable and their relative contribution is an open question.

In our study, we were unable to quantify these factors, and their exact variability between US participants and Tsimane' participants is a key open question. However, related research has found that Tsimane' children have a nuanced and rich ethnobotanical vocabulary (Martinez-Rodriguez, 2009), which is consistent with the idea Tsimane' children interact and a talk about an environment that differs from the one associated with highly urbanized cities where the majority of child development research is conducted. If these mechanisms are indeed partially responsible for the differences that we observed, then it is possible that a nuanced analysis could predict different degrees of a shape bias in Tsimane' children as a function of their vocabulary and conversational contexts within their immediate community. This is a question that we hope to explore in future work.

Conclusions

Our work shows that, when presented with identical novel objects, US participants are more likely to generalize an object label by attending to shape, compared to Tsimane' participants. Our findings suggest that the relative abundance of shape-bounded categories in people's environment, linguistic, and/or cultural context influences how they generalize novel object labels.

Author Note

This study was not preregistered. All data and analyses files are available at: https://osf.io/egc9y/

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Context of research

This project began when Edward Gibson, Roger Levy, and Julian Jara-Ettinger visited the Tsimane' to conduct experimental work with children. Unsure about what paradigms were best suited for cross-cultural developmental work, we began by testing common paradigms, including a simple generalization task from an exemplar. After a day of piloting, we noticed major differences from documented behavior of US children in a simple picture-based generalization task. In conversation with our Tsimane' interpreters it became clear that they found the instructions straightforward, but did not agree with our intuition that a shape-generalization was necessarily the right answer. In thinking about why this would be the case, we realized that a generalization by shape indeed didn't seem reasonable for many of the objects in our immediate surrounding, which led to the hypothesis and experiments presented here.

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