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Adaptive Content Biases in Learning about Animals across the Life Course

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Abstract Prior work has demonstrated that young children in the US and the Ecuadorian Amazon preferentially remember information about the dangerousness of an animal over both its name and its diet. Here we explore if this bias is present among older children and adults in Fiji through the use of an experimental learning task. We find that a content bias favoring the preferential retention of danger and toxicity information continues to operate in older children, but that the magnitude of the bias diminishes with age and is absent in adults. We also find evidence that fitness costs likely impact the types of mistakes that participants make in their attributions of dangerousness and poisonousness. These results suggest that natural selection has shaped the way in which we learn and make inferences about unfamiliar animal species over ontogeny, and that future research is needed on how content biases may vary across the life course.

Keywords Content bias · Prepared learning · Social learning · Cultural transmission · Danger · Memory

Every day, individuals are bombarded with information about the world they live in and the things that exist within it. Because it is impossible to attend to all the auditory,

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visual, and tactile information that exists in daily life, natural selection favors mechanisms that cause us to preferentially attend to relevant information in the environment (Lavie 2005). Nevertheless, the information that makes it through these perceptual filters is still likely to be greater than what memory systems are capable of encoding. Of all potentially encodable information that enters the mind, what factors determine which information is encoded into memory, and which information can be recalled in the future?

Culture-gene coevolution theory categorizes the biases that influence the transmission and acquisition of cultural information into two types: *context* biases and *content* biases (Boyd and Richerson 2005; Henrich and McElreath 2003; Rendell et al. 2011). *Context biases* are produced by cognitive mechanisms that influence the salience and likelihood of transmission of a cultural variant based on either the characteristics of the person modeling the behavior (e.g., success and prestige biases) or the distribution of traits in the population (frequency-dependent biases). *Content biases* are biases that cause the preferential transmission and retention of certain types of information over others as a function of what is being transmitted (Henrich 2009). Broadly, content biases may arise from reliably developing features of human minds (Barrett and Broesch 2012; Boyd and Richerson 1985; Boyer 1998; Sperber 1996; Tooby and Cosmides 1992) or from cultural transmission processes in which the acquisition of one cultural trait biases the acquisition of others.

In the past several decades researchers have set out to test predictions from this body of work directly, in both laboratory and field settings. Context biases in cultural transmission have been examined and supported in both the laboratory and the field (see Mesoudi 2009; Chudek et al. 2012 for recent reviews). Likewise, content biases have also received increasing attention. Although a significant amount of literature provides theory and rationale regarding the role of content biases in shaping human cognition and behavior (Atran 1998; Barrett and Broesch 2012; Boyd and Richerson 1985; Boyer 1998; Sperber 1996; Tooby and Cosmides 1992), somewhat less attention has been paid to examining the evidence for content biases empirically, particularly in field settings. Some of the strongest empirical evidence comes from laboratory-based studies in a variety of domains, including foundational studies with rats which demonstrate more rapid aversions to food stimuli vs. other stimuli when nausea is induced (Garcia and Koelling 1966); more rapid detection of fear-inducing stimuli (Öhman and Mineka 2001); higher retention of information when it is presented in a fitness-relevant context (Nairne et al. 2009); higher retention of counterintuitive, fitness relevant, and emotionally evocative elements in folklore and stories (Barrett and Nyhof 2001; Boyer and Ramble 2001; Heath et al. 2001; Norenzayan et al. 2006; Scalise Sugiyama 2001); and preferential avoidance of foods that are more likely to carry harmful pathogens (Fessler and Navarrete 2003). In each of these domains, the researchers propose that it is the fitness relevance of the information to individuals that explains preferential attention and recollection of certain types of stimuli or information over others.

Evidence for content biases from field studies is sparser, but several studies have suggested that content biases—produced as a by-product of other adaptive mechanisms—may be responsible for observed patterns of food taboos, both within (Henrich and Henrich 2010) and across (Fessler and Navarrete 2003) cultures. For example, Chudek and colleagues (under review) have argued, based on experimental evidence from adults in Fiji and Vancouver, that cultural traits associated with dualistic conceptions (e.g., souls, ghosts, body-mind switches) are content-biased, despite the monistic nature of the world, owing to application of separate cognitive systems for object tracking and mentalizing.

In this paper, we add to the existing literature on content biases with an experimental learning study conducted with indigenous Fijians living in a traditional context to evaluate if and how the strength of a content bias may vary across the life course. Learning about animals is a domain in which evolutionary theorists of cultural transmission have long predicted content biases. Modeling work has shown that when the costs of individual learning are high, such as learning based on personal experience that an animal is dangerous, social learning will be favored over individual learning (Boyd and Richerson 1985; Nakahashi et al. 2012).

Related work on prepared learning provides a parallel line of theory and evidence, which motivates our study (Öhman et al. 2001; Seligman 1970). The theoretical framework for prepared learning is that natural selection has favored the evolution of learning mechanisms which facilitate more rapid learning when stimuli and effects tend to be associated with one another over evolutionary time. For example, prior work on social learning of fear in macaques suggests a learning system with this type of adaptive design: macaques learn fear of dangerous animals from conspecifics in a single trial, but not fear of objects such as flowers, suggesting the possibility of a homologous learning mechanism in humans (Mineka and Cook 1988).

Over their evolutionary history, humans have interacted with animals in at least two ways: as predators and as prey. This means that knowledge about the predation or danger-relevant properties of animals would have had fitness value, as well as knowledge about how to catch animals for food (Barrett 2005). Many kinds of knowledge might be useful for both avoiding predators and capturing prey, including knowledge of their behavior, habitats, and diets. Consistent with this, traditional foraging people typically have extensive and elaborate folkbiological knowledge, much of it oriented toward predation and hunting (Blurton Jones and Konner 1976; Liebenberg 1990). Over human evolutionary history, there may have been opportunities for the selection of psychological predispositions that favor acquisition and retention of particularly useful information over that of less useful information in this domain—especially when there are trade-offs in what can be retained from the incoming information stream.

Our study extends a method originally developed to study content biases in learning about animals among Shuar children in the Ecuadorian Amazon, and children in Los Angeles (Barrett and Broesch 2012). In that study, Barrett and Broesch found evidence that young Shuar and American children (US age range=4.25–5.5 years, *M*=4.83; Shuar age range=4–8 years, *M*=6) preferentially remembered information about whether an animal was dangerous or safe compared with information about its diet (herbivore or carnivore) and its name, indicating a content bias in cultural transmission. Danger information was preferentially recalled immediately after training, without feedback, and after a delay of one week. Here, we seek to replicate and extend these findings with a sample of adults and older children (between 7 and 14 years of age) in Fiji, using a larger set of traits relevant to fitness for avoidance of harm, expanded now to include both harm and toxicity if eaten, and more details about the animals, including habitat and diet.

Content biases are selected for in part because of limited attentional and working memory resources: a limited-capacity system places a premium on focusing just on the information that is most crucial for fitness. If memory constraints vary across the life course, then we should expect that content biases should also vary as a function of age. As memory and attention capacity increase with age, learners may face less-stringent trade-offs because they are able to remember more information overall.

There may be other reasons why memory patterns of adults could differ from those of children, including differences in background knowledge and differences in what kinds of information are most relevant for fitness. Learners can avoid negative fitness consequences, such as death, by knowing whether an animal has the potential to inflict harm or is toxic to consume. Although knowing where an animal lives and what it eats can be useful information for obtaining prey, the learner must also possess the knowledge and skill necessary to act on that information and capture the potential prey species. Young children are less likely to possess these skills, and therefore, natural selection may have produced psychological mechanisms that favor learning and retaining information about danger and toxicity at younger ages and more equal learning across domains as individuals get older. On the other hand, given the importance of harm avoidance for survival, natural selection may favor learning and retaining danger and toxicity information regardless of age. This study will allow us to evaluate these hypotheses by examining whether content biases in this sample of Fijian adults and older children are similar to those we found in younger Shuar and US children, as well as evaluate whether our earlier findings extend to a rather different population reliant largely on marine resources.

Hypotheses

Although we utilize methods similar to those used by Barrett and Broesch (2012), several key variations allow us to examine the robustness of their findings. We expand the age range to include older children and adults, which allows us to examine how content biases vary across the life course. We also broaden the information that was presented to participants to include two more domains of knowledge: whether an animal is edible or poisonous to eat and where the animal lives. The inclusion of these additional categories allows us to evaluate how learning biases vary as a function of why they are relevant for fitness—in other words, avoiding harm (dangerousness and poisonousness) and acquiring prey (diet and habitat).

Hypothesis 1 *Adults and older children will exhibit single-trial learning without feedback.*

Barrett and Broesch found that a single presentation of information was sufficient for young children to learn if an animal is dangerous. Given the increased memory and attentional resources of older children and adults, we expect to find similar evidence of single-trial learning in our study. However, given these increased cognitive resources, we expect that single-trial learning should occur for all four types of information (Danger, Poison, Habitat, and Diet) presented to the adults and older children in our sample.

Hypothesis 2(a) *Adults and older children will exhibit preferential retention of information in the domains of danger and poison.*

In general, we expect our findings to support and expand Barrett and Broesch's evidence for greater recall and retention of danger information compared with diet information. We hypothesize that this effect was observed because of the difference in why this information is fitness-relevant—in other words, avoiding harm vs. acquiring food resources. Therefore, we hypothesize that poison and danger information should be preferentially retained compared with habitat and diet information.

Hypothesis 2(b) *The magnitude of the content bias favoring the retention of danger and poison information will be larger for children than for adults.*

However, cultural transmission biases may exhibit developmental changes, such that a bias that is present in adults might not be absent or attenuated in children, or vice versa. For example, Fessler (2006) finds that in 19 societies reliant upon using fire as a tool, interest in fire is reported to peak during middle childhood and wanes thereafter. This developmental trend facilitates a mastery of fire-related tools and techniques early in life. In the case of learning about animals, there are reasons to expect some possible differences between adults and children, and especially the young children of 3 years and up tested by Barrett and Broesch. A young child of 4 or 5 years is entering the world with relatively little folkbiological background knowledge and yet faces very real dangers and threats. For example, predatory marine species, such as sharks, and the bioaccumlated reef toxin *ciguatera* are common potential hazards in Fiji. To such a child, even very basic information such as what is safe and what is dangerous could provide a significant survival boost and might therefore be highly memorable. As children grow, however, they soon start foraging and begin to acquire folkbiological knowledge (Bird and Bliege Bird 2002). By adolescence, children in most foraging societies are typically competent foragers with substantial folkbiological knowledge. How new information about animals is processed by such an individual could therefore be quite different than how it is processed by a five-year-old. For example, by adulthood individuals in most societies may have learned most or all of the animals that they will ever need to know about in their local environment, suggesting that selection for retaining rapid learning biases in adulthood might be weak. On the other hand, adults' memories are better overall than those of children, and they have substantial background knowledge with which to interpret new information. For reasons such as these, predictions regarding content biases in adult foragers are not as straightforward as they are for younger children. A goal of this study, then, is to empirically assess whether and how memory for novel animal information changes with age.

Hypothesis 3 *Participants should err on the side of caution (error management) in their attribution of dangerousness and poisonousness in both the experimental and control groups.*

Some mistakes can be more costly than others. If an individual misidentified a dangerous animal as safe, it could be a potentially very costly mistake in terms of fitness (death or injury), whereas misidentifying a safe animal as dangerous would have much lower costs (avoiding a potential prey species). Error management considerations would predict that individuals should err on the side of caution (e.g., more likely to identify a safe animal as dangerous, rather than identifying a dangerous animal as safe). Given these considerations, we predicted that participants should be more likely to make the less-costly error in both the control and experimental conditions.

Methods

Participants

The study participants came from three villages in the Fiji Islands. The adult sample was composed of 92 individuals from two separate parts of Fiji, 52 from the island of Totoya and 40 from the island of Yasawa, between the ages of 17 and 79 (M=40.29, SD=15.94, sex ratio (F:M)=1.47). Within the Totoya sample, a control group comprised 11 individuals while an experimental group contained 41 individuals. Logistical constraints prevented the collection of the secondary recall data for 28 of the 41 participants in the experimental group in Totoya, leaving 13 who completed the entire experiment in this condition. All 40 individuals from the island of Yasawa were in the experimental group, and all completed both rounds of data collection. The sample of children came entirely from Yasawa Island, 13 in the control group and 17 in the experimental group. All children were between the ages of 7 and 14 (M=10.5, SD=1.93, sex ratio=0.88). Study protocols were approved by Emory University's IRB, and informed consent was obtained for all adult participants, as well as assent from children and consent from their parents.

Stimuli

Twenty animals were selected as exemplars, using a 5×4 design, balancing scientific taxonomic categories with various levels of fitness threats. The taxonomic categories were mammal, bird, reptile/amphibian, fish, and an additional category of animals that were taxonomically ambiguous based on physical appearance alone. Animals were selected to fill four different categories that varied in their fitness threats: (1) dangerous but not poisonous, (2) poisonous but not dangerous, (3) poisonous and dangerous, and (4) neither dangerous nor poisonous. It was possible to find species exemplars for all categories with the exception of a bird that is both poisonous and dangerous. While some of the species in our stimuli were also used by Barrett and Broesch (2012), significant modifications were made in order to accommodate the 5×4 design of our study. All species chosen were non-native to Fiji, and only true biological information was given to participants. To control for order and fatigue effects, we randomized the order of presentation of the animals. This randomization was done by creating four versions of the stimuli and information for presentation. Participants were presented with information using one version, and all subsequent interviews were done with another version.

Information Presentation

Participants were told that they were going to participate in a task in which they would hear various types of information about animals and then be asked questions about those same animals. They were presented with a picture of the first animal and told whether it was dangerous or safe (Danger), poisonous to eat (Poison), where it lives (Habitat), and what it eats (Diet). For example, if the first species was a polar bear, the image would be placed in front of the participant and the experimenter would say, “This animal is a polar bear. It lives in open areas. It is dangerous. If you eat it, you can get sick. It eats only other animals.” We randomized the order in which these domains of information were presented for each species in each of the four versions of the stimuli to control for order effects. Participants were allowed to inspect the image, and after they were finished, the experimenter moved on to the next species. This process was repeated until the participant had seen all 20 species.

Initial and Long-Term Recall

To determine what information was encoded from the information presentation, participants were asked questions about each species immediately following the information presentation. The experimenter would begin by saying, “I would like to ask you a few questions about the animals I just told you about.” Participants were then shown an image of one of the 20 species (species were in a different random order than the version used in the information presentation) and asked the following questions: (1) What is this animal’s name? (2) Do you think this animal is dangerous? (yes/no) (3) Do you think this animal is poisonous to eat? (yes/no) (Literal translation: Would you get sick if you ate it?). (4) Where do you think it lives? (Forced choice from 10 options). (5) What do you think it eats? (Forced choice from 7 options). All forced choices (listed in Table ESM-1) were presented (both visually and orally) for participants to choose from. These questions were then repeated for the remaining 19 animals. To determine what information was remembered after a longer period of time, participants were again asked to answer the questions outlined above approximately one and one half weeks following the information presentation.

Control Group

Although all species in this task were non-native to Fiji, it is not safe to assume that participants would respond as if they were guessing randomly had they not been given any information about the species. Background knowledge or visual information contained in the stimuli may have caused participants to perform better than random guessing. Individuals may also have acquired heuristics from prior learning about other animals that would allow them to make educated guesses about novel species, which could result in higher performance than random guessing. Finally, given that the choices for danger and poison were dichotomous, whereas habitat and diet were polychotomous (10 and 8 choices, respectively), it is necessary to control for the differential likelihood of guessing correctly even if a participant was guessing randomly.

All of these obstacles are surmountable by using the performance of a control group as a baseline measure of the likelihood of answering each question correctly. Participants in the control group were asked the questions regarding each species described above but were not presented with any information about the species beforehand. Using this data as a baseline, instead of what might be expected as a result of random guessing, allows us to more rigorously evaluate our data. For example, one assumption of our experimental design to test for content biases is that participants learned something as a result of being presented with information about these animals. However, participants might perform better than random guessing for the reasons mentioned above, even in the absence of information. Without the use of the control group, we could falsely conclude that learning occurred if participants performed better than would be predicted based on random guessing. By comparing differences in performance between the control group and initial recall performance in the experimental group we are able to rigorously evaluate the effect of being told information about the species controlling for background knowledge, visual information contained in the stimuli, and educated guessing, which could also explain performance differences across domains.

Results

Analytic Approach

The evaluation of the majority of our hypotheses rests on accurately determining if participants are learning new information about the animals in this task, and determining the relative amount of learning and retention that occurs depending on the type of information provided (i.e., dangerousness, poisonous to eat, habitat, and diet). To evaluate this systematically, we utilized a generalized linear mixed effects model (GLM model) regression approach, using the lme4 package in R (Bates and Maechler 2010; R Development Core Team 2010). This statistical approach allows us to control for the non-independence of responses (i.e., participants responded to multiple questions, and multiple participants were responding to the same set of questions) by including random effects variables for participants and questions. This effectively captures the variance in question difficulty and differential participant aptitude into the error term for the model. The dependent variable in these regressions is whether participants answered correctly or incorrectly. Since this is a binary variable, binomial regressions with logit link functions were used.

For the purpose of clarity, here we present only those results that are relevant to our initial hypotheses, but we provide additional details in the Electronic Supplementary Materials.

Hypothesis 1

Summary of Findings Our results support this prediction; both adults and older children show evidence for single-trial cultural learning without feedback.

Single-Trial Learning To evaluate this hypothesis, we first established a baseline likelihood of responding correctly, in the absence of any information, via the performance of the control group. Parameter estimates for the control group in Table 1 do not indicate any statistically significant departures from what would be expected via random guessing for both adults and children (see ESM for details).

We evaluate the evidence for single-trial learning by examining the parameter estimates for Initial Learning, which are also presented in Table 1. These odds ratios

Table 1 Likelihood of Responding Correctly to a Question

		(a) Adults' Performance				**(b) Children's Performance**			
		Odds Ratio	**Lower 95% CI**	**Upper 95% CI**	***p***	**Odds Ratio**	**Lower 95% CI**	**Upper 95$ CI**	***p***
Control Group	**Danger**	1.76	0.86	3.59	0.12	1.58	0.87	2.88	0.13
	Poison	1.02	0.51	2.07	0.95	1.15	0.63	2.08	0.65
	Habitat	0.19	0.09	0.39	**<.001**	0.21	0.11	0.39	**<.001**
	Diet	0.70	0.35	1.40	0.31	0.08	0.04	0.16	**<.001**
Initial Learning	**Danger**	1.80	1.19	2.72	**0.006**	1.46	0.97	2.21	0.07
	Poison	1.52	1.03	2.25	**0.037**	1.18	0.79	1.77	0.42
	Habitat	1.95	1.26	3.01	**0.003**	2.14	1.34	3.42	**0.001**
	Diet	1.26	0.85	1.85	0.25	0.60	0.32	1.12	0.11
Secondary Recall	**Danger**	0.92	0.74	1.13	0.42	0.88	0.62	1.25	0.46
	Poison	0.86	0.71	1.05	0.14	0.90	0.64	1.26	0.54
	Habitat	1.06	0.87	1.30	0.54	0.68	0.46	0.99	**0.047**
	Diet	1.39	1.15	1.67	**<.001**	0.95	0.51	1.77	0.87
		Question and Participant were included as random effects. Question Variance: 1.86 log-odds, SD = 1.36 log-odds Participant Variance: 0.11 log-odds, SD = 0.34 log-odds Control Group, *N*=11; Experimental Group, *N*=81				Question and Participant were included as random effects. Question Variance: 1.37 log-odds, SD = 1.17 log-odds Participant Variance: 0.06 log-odds, SD = 0.24 log-odds Control Group, *N*=13; Experimental Group, *N*=17			

(a) and (b) present the results of the GLM models of participant performance for adults and children, respectively. Random effect estimates for participants and questions are reported below each table. All parameter estimates are presented as odds ratios. The parameter estimates for the control groups represent the odds of responding correctly to a question in a given domain compared with a 50% likelihood of responding correctly. Values greater than 1 indicate a >50% likelihood of responding correctly. *P* values represent the statistical significance of the difference from 50% and therefore are of little practical significance for diet and habitat since there were more than two choices. The parameter estimates for Initial Learning represent the odds of responding correctly on a question in a given domain in the experimental group shortly after being told information about each animal compared with the odds of the control group responding correctly in the same domain. Odds ratios greater than 1 for Initial Learning indicate an increase in performance compared with the performance of the control group, and *p* values provide an estimate of the statistical significance of any differences. The parameter estimates for Secondary Recall represent the change (after ~1.5 weeks) in performance in a given domain from what was learned initially. Odds ratios less than 1 indicate a decrease in performance compared with the Initial Learning performance, and *p* values represent the statistical significance of the change in performance between Initial Learning and Secondary Recall. (bold values are significant)

represent the increase in performance relative to the control group in each domain. Adults in the experimental group performed better than the control group on questions about danger, poison, habitat, and diet, but the increase in performance for diet was not statistically significant at conventional levels (see Initial Learning odds ratios in Table 1, Fig. 1, and corresponding captions). The magnitudes of the learning effects indicate that performance increased substantially. For example, an adult in the experimental group has 1.8 times the odds of correctly answering a question about danger compared with an adult in the control group.

Children showed statistically significant increases in performance relative to the control group for habitat, and increases in performance for danger and poison that are not statistically significant at conventional levels (see Initial Learning coefficients in Table 1 and Fig. 1). Children in the experimental group performed worse than the control group on diet questions, but this difference is not statistically significant.

Hypothesis 2(a) and (b)

Summary of Findings We find some evidence in support of Hypothesis 2a for children and no evidence for a retention bias for adults. We observe a statistical trend toward an age by domain interaction among children, with poorer performance only in the danger domain as children get older. The presence of this age trend for danger and weak evidence for a retention bias after 1.5 weeks for children, but not adults, provide some support for Hypothesis 2b.

Content Biases in the Retention of Information Our hypotheses regarding content biases are best evaluated by first determining how much information was learned as a result of

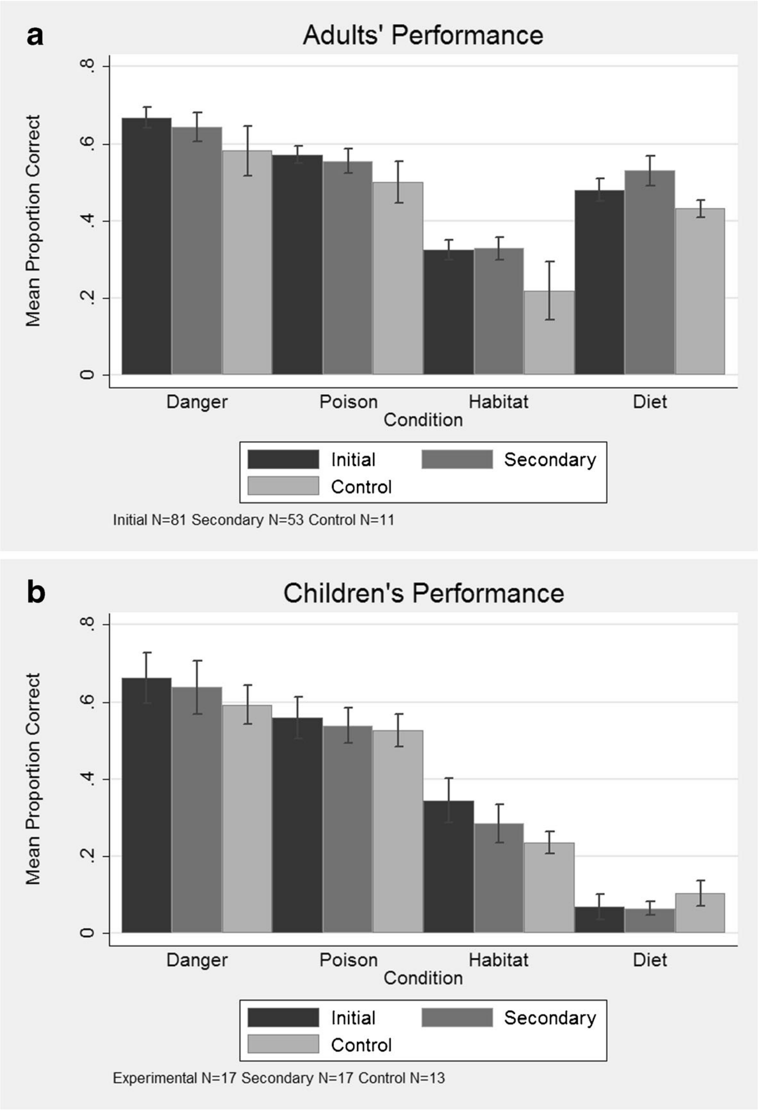

Fig. 1 Comparing Performance between Control Groups and Experimental Groups. These plots illustrate the performance difference between the control groups and the experimental groups at both time points. The experimental groups perform better in all domains (except diet for children), but not all of these differences are statistically significant at conventional levels. The likelihood of randomly guessing a correct response varies by domain and explains some of the between-domain variation in performance reflected in this figure. Error bars represent 95 % confidence intervals

the information presentation (parameter estimates for Initial Learning in Table 1), and then by evaluating how much of that increase in performance was retained 1.5 weeks after the information presentation (parameter estimates for Secondary Recall in Table 1).

Our initial recall results indicate statistically equivalent learning in all domains for adults. Results for children appear on the surface to be mixed, with lower values in diet than in all other domains. However, there was no evidence for learning in diet compared with the control group, which minimizes practical significance of these statistical differences. Learning was significantly less for poison than for habitat among children (see ESM for more details).

While the Initial Learning results are one way to test for short-term content biases in learning, they also provide information on the efficacy of the experimental paradigm for presenting information to participants. Differences in performance by domain at this level could reflect either differential effectiveness of the information presentation between domains or preliminary support for a content bias in learning. Therefore, performance differences between domains immediately following the information presentation alone do not provide a robust examination of our hypotheses.

A more relevant test for long-term patterns of cultural evolution is achievable by evaluating how much of the performance boost resulting from information presentation was retained after 1.5 weeks. Our GLM models allow us to factor in the amount of initial learning and compare the retention of newly learned information between domains (see parameter estimates for Secondary Recall in Table 1). Although a comparison of the odds ratios and their confidence intervals in Table 1 can serve as simple heuristic for determining if there are any significant differences in performance between domains, we also systematically evaluate this by running a series of GLM models in which we sequentially vary the reference category. This allows us to compare performance between every possible pair of domains. We discuss the results of both this analysis and the primary GLM model presented in Table 1.

Adults' Long-Term Recall Biases For adults, we observe decreased performance in the danger and poison domains and increased performance in the habitat and diet domains. However, the magnitude of the differences for danger, poison, and habitat are small and not statistically different from 1. This demonstrates that adults remember what they have learned for danger, poison, and habitat, indicating no evidence of a content bias between these domains of information. The only domain with a significant difference in performance was diet, for which adults demonstrate an increase in their performance. When we make comparisons between domains by varying the referent category in a series of GLM models (results not shown here), the only significant differences we observe are between diet and the other domains. The significant increase in performance for the diet domain is puzzling, and we speculate about this result in the Discussion.

Children's Long-Term Recall Biases For children, we observe decreased performance in all domains, but this decrease is only statistically significant for habitat. The decreases in performances for danger and poison are very similar to each other, but both are smaller than the decrease for habitat, which indicates weak evidence in support of a content bias in children for preferential retention of danger and poison information relative to habitat information. The decrease in performance for diet was very small, but this is because there was no learning about diet initially. When we sequentially vary the referent category in a series of GLM models, we find no statistically significant differences in retention between any of the domains.

Content Bias by Age In subsequent analysis, we include an age by domain interaction term in our GLM model for children (results presented in Table 1). We find a marginally significant interaction between age, centered to the mean, and danger (GLMM-OR: 0.92, $Z=-1.688$, $p=0.091$), indicating poorer retention of danger information as children got older. For the other domains where learning occurred, poison and habitat, interaction terms effect sizes were small and not statistically significant (poison: GLMM-OR: 0.98, $p=0.65$; habitat: GLMM-OR: 1.02, $p=0.73$).

The absence of a recall bias for adults, the weak evidence for a recall bias in older children after 1.5 weeks, and a marginally significant age by domain interaction for only danger information all provide some support for a developmental trend, which we explore further in the Discussion.

Hypothesis 3

Summary of Findings We found strong evidence in support of this prediction. Participants are significantly less likely to make a mistake with high potential fitness costs in all groups and ages for dangerousness, and in all groups except adults in the control condition for poisonousness.

Error Management Biases We tested this prediction in two ways. First, we examined whether there was a response bias toward saying animals are dangerous or poisonous on the whole. Binomial tests confirmed that both adult and child participants were significantly more likely to respond that an animal was dangerous rather than safe, and poisonous rather than edible, for both the control and experimental conditions ($p<0.05$ for all tests; see Table 2). For the danger domain, this was true whether tested against expected probabilities of 0.45 (actual proportion of animals in stimuli that were dangerous) or 0.5 (probability based on random guessing). From this we concluded that there was a general bias; participants were more likely to say an animal was dangerous both without prior information (as evidenced by the control group) and with prior information (experimental group). For attributions of poisonousness, we observed the same general bias—participants were more likely to say an animal was poisonous rather than edible (see Table 2).

For the second test of this prediction, we focused on instances in which participants made errors in their danger or poison attributions to see if the direction of errors was in line with the predictions from evolutionary theory regarding error management. If errors were equally likely, one would expect participants to mistakenly identify safe animals as dangerous just as often as they mistakenly identified dangerous animals as being safe. Binomial tests confirmed that the direction of errors was biased and consistent with predictions from evolutionary theory regarding error management (see Fig. 2). When adults and children made mistakes, they were significantly more likely to misidentify a safe animal as being dangerous, rather than mistaking a dangerous animal as being safe. The same trend was present for the errors regarding whether or not an animal was poisonous to eat; however, this was not significant for the adults in the control group.

Table 2 Participant Attributions of Danger and Poison

		(a) Adults			(b) Children		
Group	**Domain**	**Observed Proportion**	**Expected Proportion**	***p***	**Observed Proportion**	**Expected Proportion**	***p***
Control Group	**Danger**	0.66	0.50	**<.001**	0.71	0.50	**0.005**
		0.66	0.45	**<.001**	0.71	0.45	**<.001**
	Poison	0.56	0.50	**0.034**	0.68	0.50	**<.001**
Experimental Group	**Danger**	0.59	0.50	**<.001**	0.57	0.50	**<.001**
		0.59	0.45	**<.001**	0.57	0.45	**<.001**
	Poison	0.63	0.50	**<.001**	0.68	0.50	**<.001**
		Control Group N=11, Experimental Group N=81 Each Participant Responded to 20 Questions			Control Group N=13, Experimental Group N=17 Each Participant Responded to 20 Questions		

(a) and (b) present the results of binomial tests comparing participants' attribution of whether animals were dangerous or poisonous to what would be expected based on chance (50%), or based on the actual proportion in the stimuli (45% of animals were actually dangerous; exactly 50% were poisonous). All conditions, age groups, and domains exhibited a bias toward saying that animals were dangerous or poisonous (all $p<0.05$)

The combined results of these analyses indicate that there is a general bias toward erring on the side of caution. We find evidence for this in both the control group and the experimental group. The fact that it is present in the control group suggests there may be a general bias toward saying that animals are dangerous or poisonous to eat in the absence of other information. The presence of this bias in the experimental group suggests that it may continue to operate when participants do have some information but may be less than certain of species' true characteristics.

Discussion

The results of this study indicate the following: (1) Both adults and children between 7 and 14 years old exhibit single-trial learning of information about animals without feedback, replicating the findings of Barrett and Broesch; (2) There is weak evidence for a content bias in long-term recall (retention) in the children age 7 to 14 in our sample, and a statistical trend to suggest that this content bias for danger information diminishes as children in our sample age. While these results partially replicate the findings of Barrett and Broesch (2012), they suggest that the strong advantage of learning of danger over learning of diet and name information in children under age 7 may not generalize to older children and adults; and (3) Both adults and children in our sample exhibit a bias toward erring on the side of caution when attributing whether an animal is dangerous or poisonous to eat, in the absence of other information or when they are uncertain. This finding fits with predictions from standard evolutionary approaches (Haselton and Nettle 2006; McNamara and Houston 1992).

Our findings partly replicate and strengthen the conclusions reached by Barrett and Broesch (2012). Our sample comes from a different cultural context, with an older age range of participants, and we provided participants with two types of information about animals that were not included in the previous study: poison and habitat. We found strong evidence for single-trial learning without feedback for both adults and children in our sample. Whereas Barrett and Broesch only found evidence for single-trial learning for danger information, we observed learning occurring in all domains with the exception of diet among children. This may be due to the increased attention and memory capacities of the older children and adults in our sample, leading to reduced trade-offs in the form of competition for attention and encoding than in the younger children studied by Barrett and Broesch, as well as, perhaps, increased fitness-relevance of these other categories of information for adults (discussed below).

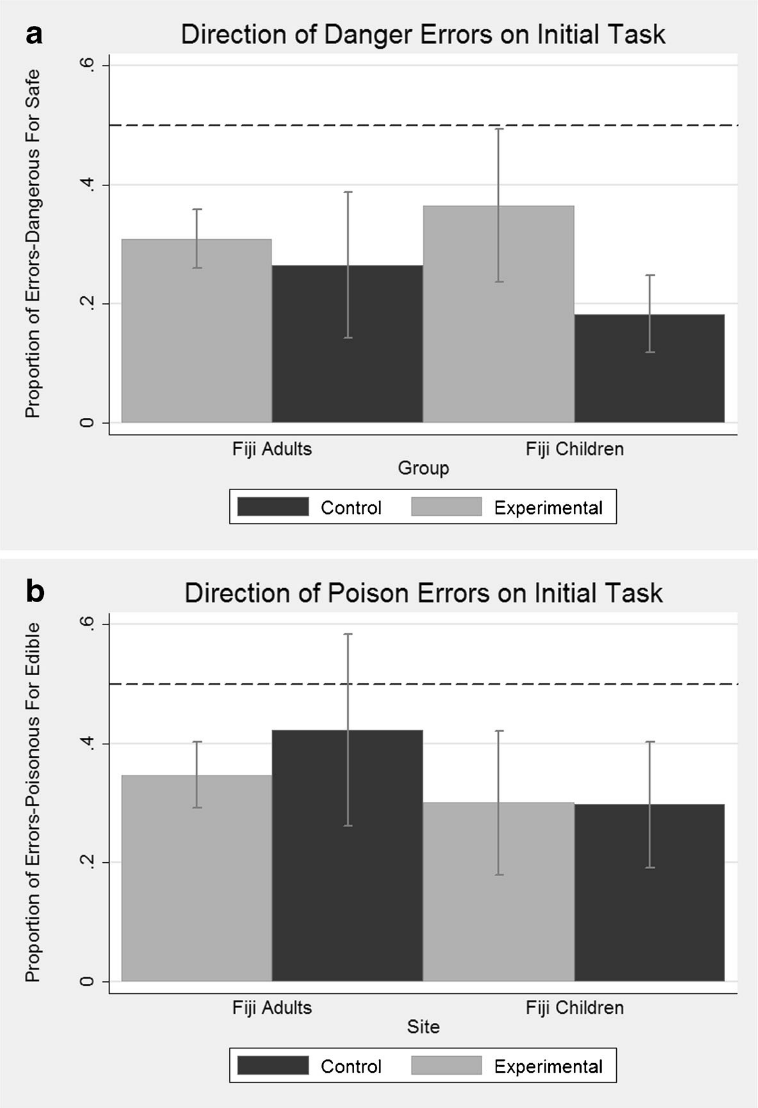

Fig. 2 Direction of Errors in Attribution. These graphs illustrate the direction of errors that participants made in their attribution of whether animals were dangerous or poisonous. The dashed line (0.5) indicates what one would expect if participants were equally likely to make both kinds of mistakes. The fact that the proportion of errors and their corresponding 95% confidence intervals for both adults and children in the control and experimental groups are below this line indicates that they are more likely to make the less-costly mistake. Error bars represent 95% confidence intervals

While our examination of biases in the recall of information replicates some of the findings of Barrett and Broesch (2012), the general pattern that Barrett and Broesch found (that information on danger is strongly preferentially retained relative to diet and name in 4- to 5-year-old US children and 4- to 11-year-old Shuar children) only partly holds in Fijian children aged 7 to 14. We found evidence in this age group for preferential retention of danger and poison information compared with habitat information in long-term recall, but not for Fijian adults. Because children show little evidence of learning anything about diet initially, we are unable to use this domain to further test the robustness of the differences in retention of information as a function of why it is relevant for fitness. We also observe a statistical trend in which the preferential retention of danger information about animals diminishes with age.

We found no systematic evidence for preferential initial learning of information as a function of information type for adults, which is different than the content bias for danger learning found by Barrett and Broesch in young children. For children in our sample, we found limited evidence that participants initially learned more about habitat than poison (but not danger), which does not systematically support or conflict with Barrett and Broesch's findings. In all other instances when learning did occur, the difference between domains in the amount of learning was not statistically significant, nor was the magnitude of the coefficients suggestive of any strong bias favoring learning danger and poison information over diet and habitat information. This leads us to conclude that within the domains tested, the type of information has no consistent effect on encoding and immediate recall of information in older children and adults.

Decline in recall is relatively small in all domains for adults, indicating that they remember most of what they learned initially. The observed increase in performance for diet is difficult to interpret. Initially we thought that this might have been due to the fact that not all adults completed the secondary recall, and that we effectively introduced a selection bias in the data in which the participants who were tested on the secondary recall learned more about diet than the entire sample in general. However, when we restrict the analysis to only adults who completed both rounds (analysis not shown here), we observe the same pattern. While we are unable to determine why we find this result, we speculate that this is a false positive (Type I error), and we would not expect to see the same pattern if the study were replicated.

Although we predicted information on danger and toxicity would be preferentially retained by children and possibly adults, we only observed this effect in children. We can make no definitive conclusions regarding why we observed a developmental trend in learning biases, but we suspect there may be a difference in the relevance of different kinds of information about animals for adults vs. children, and in how it is processed. Although many Fijians begin in late childhood and adolescence to engage in the more-challenging marine foraging tasks, such as spear fishing underwater, their knowledge of local species and common hazards is already substantial. Children in Fiji, as in other foraging societies, are exposed to this information from their first years of life. They routinely see and hear about local fauna when others return to the village with their catch, while accompanying kin and other village members on foraging trips, and while exploring the environment around the village with other children. Everyday conversation within the village is another source of this information for young children, as stories about fishing, including encounters with hazards such as sharks, are a favorite topic of discussion.

By late childhood or adulthood most individuals in foraging societies already know something about most of the animals they are likely to encounter, so how they might receive knowledge of novel animals—ones that are clearly not present in their local environment, and that they are therefore not likely to encounter—is difficult to predict. For children in the learning phase of early childhood, however, being shown a new animal and told it could hurt them might have much more impact, against their relatively sketchy background knowledge of animal biology and the local fauna, than it would for a seasoned adult forager or fisher. It is possible that in early childhood there is a learning window for rapidly acquiring information about novel animals that is not active in the same way in later childhood or adulthood (Barrett 2004).

Moreover, the fact that adults showed long-term retention of information about animals for *all* the information types we presented is consistent with the idea that many forms of information about animals, including diet and habitat, are likely to be useful for adult foragers, and therefore that they might have good memory for all of these categories (Medin and Atran 1999). In order to test this further, however, future studies would have to compare entirely different categories of information, perhaps about entities other than animals, to see if adults have superior memory for all foraging-relevant information about animals, as opposed to other categories of information (see Nairne et al. 2009).

Finally, we found evidence that both adults and children err on the side of caution in the attribution of whether or not an animal is dangerous or poisonous to eat. This finding is consistent with predictions from evolutionary theory regarding error management, and this trait could have positive fitness consequences for individuals when they encounter unfamiliar species. One question that we were not able to fully explore is the degree to which this bias may be the result of living in an ecosystem where dangerous and poisonous animals are fairly common, such as in Fiji. Further studies are necessary to determine if this bias is a universal characteristic of human minds or if it is socially learned. If the latter is true, then we would expect this bias to diminish in cultural or ecological contexts where the risks of encountering a dangerous or poisonous species are smaller (e.g., urban USA).

Limitations

This study has several limitations. First, the ability to make generalizations outside this sample population (a Fijian village) is limited. The types of biases we have documented, such as the safe/dangerous error bias, may not be present in other groups if it is culturally acquired. Given that Barrett and Broesch (2012) present similar results with both U.S. children and Shuar children, albeit younger children than those in our sample, there is support for the hypothesis that this may be an evolved feature of human memory and judgment systems. However, it is impossible for us to exclude the possibility that the relationship that we observe between age and the strength of content biases in learning about animals may be a unique feature of the Fijian context. It is possible that in other cultural contexts, the biases that Barrett and Broesch (2012) report may be preserved into adulthood, or be absent all together. Further work with Fijian children closer in age to those who constituted Barrett and Broesch's sample, along with young children, adolescents, and adults in other diverse cultural contexts, is necessary to provide a more rigorous evaluation of the universality of our findings.

Second, our sample's limited size (especially for children) minimizes the statistical power and therefore the ability to draw conclusions. We have identified results that are statistically significant at the conventional level of $p < 0.05$ throughout this paper, but some readers may be less inclined to support our interpretation of differences where $p > 0.05$. Statisticians have long acknowledged that there are limitations to hypothesis testing and the use of p values as the sole measure of statistical inference (Carver 1978; Gardner and Altman 1986). We believe there is merit in the use of both p values and alternative methods, which is why we have made these distinctions. However, we also discussed instances in which the magnitude of difference was large and might become statistically significant at conventional levels with a larger sample.

Conclusion

The human species has a long evolutionary history of sharing ecosystems with potentially dangerous or toxic species. Given the strong fitness consequences of encountering a dangerous animal or consuming a poisonous animal, cultural evolutionary theory predicts that learning about animals would be a domain in which content biases may privilege the retention of this type of information over other kinds of information about animals. This study replicates some of the results observed by Barrett and Broesch (2012) and presents evidence in support of this hypothesis, especially in children. However, the lack of an observed content bias in the adult population, and the weaker evidence for the older children in our sample relative to the younger children in the study by Barrett and Broesch, suggests that there may be a developmental window for this content bias. Future work should focus on theorizing and studying how content biases emerge and change over the life course.

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