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Abstract: Prior work by Barrett and Broesch (In Press) demonstrated that young children in the US and Ecuador preferentially attend to and remember information about if an animal is dangerous over its name or what it eats. Here we expand on this prior work by exploring how this bias may or may not operate among older children and adults living in Fiji. Participants engaged in an experimental learning task, where they were told various types of information about a 20 species of animals not found in Fiji and tested on how much information they learned immediately, and retained after a week and a half. We find evidence that a content bias for the retention of fitness relevant information continues to operate in older children, but that the magnitude of the bias diminishes with age and is not present in adults. We also find evidence that fitness costs likely impact the types of mistakes that participants make in their attribution of if a species is dangerous or poisonous. These results suggest that natural selection has shaped the way in which we learn and make inferences about unfamiliar animal species, and that future research is needed on how content biases may vary across the lifecourse.



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Dear Editor of Evolution and Human Behavior,

Thank you for your consideration of our manuscript: [Adaptive Content Biases in Learning about Animals Across the Lifecourse](#). In this manuscript, we present original research which explores how content biases in learning about animals vary across the lifecourse. While we utilized methods similar to those outlined in Barrett and Broesch, which is in press at EHB, here we explored how content biases operate across a much wider age range, with more types of information, and in a different cultural context than our prior work. The findings are novel, and build on the existing literature in this area. A prior version of this manuscript was published as a chapter in James Broesch's dissertation. This manuscript has undergone very significant modifications since the dissertation version.

All protocols were approved by Emory University's Institutional Review Board at the time the study was conducted, and subsequently were approved by the University of Wisconsin-Madison's IRB during the write-up phase. Informed consent was obtained for all adult participants, as well as assent from children and consent from their parents. All co-authors have seen and approved this manuscript. We would like to thank you again for your consideration, and look forward to hearing from you.

Sincerely,

James Broesch, Joseph Henrich, and Clark Barrett

Adaptive Content Biases in Learning about Animals Across the Lifecourse

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Adaptive Content Biases in Learning about Animals Across the Lifecourse

Introduction

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, 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?

One approach to answering this question has come from research in culture-gene co-evolutionary theory (Boyd & Richerson, 1985; Henrich & McElreath, 2003). Using evolutionary models, theorists have proposed and demonstrated how various psychological biases can evolve genetically via natural selection as well as how they can illuminate many of the population level characteristics observed in human cultural evolution (Boyd, Richerson, & Henrich, 2011), such as cumulative cultural evolution, costly displays, social stratification, and ethnicity (Henrich, 2009; McElreath, Boyd, & Richerson, 2003).

In constructing a psychologically-grounded framework for thinking about cultural evolution, Henrich and McElreath (2003) broadly distinguished between two types of biases that influence the transmission and acquisition of cultural information: *context* biases and *content* biases (Boyd & Richerson, 1985, 2005; Henrich & McElreath, 2003). *Context biases* reflect cognitive mechanisms that influence the salience and likelihood of transmission of a cultural variant, based on the contextual environment in which it is transmitted. These biases can be associated either with the person modeling the behavior (success and prestige biases) or the distribution of information within the population (frequency-dependent biases). *Content biases* are biases that cause the preferential retention of certain behaviors or 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 (Chudek, Mcnamara, Birch, Bloom, & Henrich, n.d.), or from cultural transmission processes in which the acquisition of one cultural trait biases the acquisition of others.

In the past 10 years researchers have set out to directly test these predictions, particularly context biases in social learning, in both laboratory and field settings. Developmental psychologists have found evidence which supports theoretical predictions regarding context biases based on the age (Jaswal & Neely, 2006; VanderBorgh & Jaswal, 2009), similarity (Harris & Corriveau, 2011), dialect (Kinzler, Corriveau, & Harris, 2011; Shutts, Kinzler, Mckee, & Spelke, 2009), success and skill of the model (i.e. person being learned from) (Birch, Akmal, & Frampton, 2010; Chudek, Brosseau-Liard, Birch, & Henrich, forthcoming; Jaswal & Malone, 2007) and prestige (Chudek,

Heller, Birch, & Henrich, 2012). Other research provides evidence that conformity biases, a frequency-dependent context bias, operate among adults engaging in an experimental task (Efferson, Lalive, Richerson, McElreath, & Lubell, 2008).

Anthropologists have also found supporting evidence for context biases based on the prestige and success of models in field settings (Henrich & Broesch, 2011; McElreath et al., 2008; Reyes-García et al., 2009; Reyes-Garcia et al., 2008) (see Chudek et al., forthcoming for a recent review).

Empirical evidence for content biases has not been pursued as vigorously as research on context biases. Some of the strongest empirical evidence comes from laboratory based studies (J. L. Barrett & Nyhof, 2001; Heath, Bell, & Sternberg, 2001; Nairne, Pandeirada, Gregory, & Van Arsdall, 2009; Ohman, Flykt, & Esteves, 2001). Evidence from field studies is sparser, but several studies that have suggested that content biases may be responsible for observed patterns of food taboos, both within (Henrich & Henrich, 2010) and across cultures (Fessler & Navarrete, 2003). However, few studies that have utilized experimental tools to rigorously examine how these biases may or may not operate in field settings.

In this paper, we seek to bridge this gap using an experimental learning study conducted with indigenous Fijians living in a traditional context. Our study extends a method originally developed to study learning about animals among children living among the Shuar of the Ecuadorian Amazonia and in Los Angeles (H. C. Barrett & Broesch, in press). In that study, Barrett and Broesch found that young Shuar and

American children (US age range 4 years 3 months to 5 years 6 months, mean age 4 years 10 months; Shuar age range 4 to 8 years, mean age 6 years) preferentially remembered information about whether an animal was dangerous or safe compared to information about its diet (herbivore or carnivore) and its name, indicating a content bias in learning. Here, we seek to extend and replicate 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, and using categories of information that are both of potentially high fitness relevance (if animals are dangerous or poisonous to eat) and potentially lower fitness relevance (what animals eat and where they live). Content biases are selected for in part because of limited attentional and working memory resources: in a limited capacity system, there is a premium on focusing on just the information that is most crucial for fitness. As memory and attention capacity increase with age, learners may face less stringent tradeoffs because they are able to remember more information overall. This study will allow us to test this idea by examining whether content biases in this sample of Fijian adults and older children are similar to those we found in younger Shuar and U.S. children, as well as evaluate if our earlier findings extend to a rather different population reliant largely on marine resources.

Prior Evidence for Content Biases

To develop an evolutionary understanding of content biases and their implications for learning, it's useful to consider why natural selection might have favored such a bias. Limitations on attention and memory encoding can help to explain why certain pieces of information may be prioritized over others. If tradeoffs in attention and memory exist, as

they almost surely do, then devoting cognitive resources to perception and encoding of one piece of information, such as a property of an object, entails fewer resources available to encode other features of the object (Schaller, Park, & Kenrick, 2007). Attention is a limited resource, and therefore it has been proposed that it should be allocated to the most relevant features in order to maximize the adaptive capacities of cognition (Gigerenzer, Todd, & ABC Research Group, 2000; Schaller et al., 2007).

Content biases provide a mechanism for directing attention, learning, and cultural transmission to the most relevant features and cultural variants¹, in such a way as to optimize fitness benefits (Boyd & Richerson, 1985). Boyd and Richerson (1985 p. 137-157) use mathematical models to demonstrate the specific conditions under which content biases would be favored by natural selection: when the cost of evaluating possible variants is low or when the costs and benefits of traits are salient to the learner.

Researchers have found evidence which supports the existence of content biases in a variety of domains, including: more rapid aversions to food stimuli vs. other stimuli, when nausea is induced (Garcia & Koelling, 1966); 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 (J. L. Barrett & Nyhof, 2001; Boyer & Ramble, 2001; Heath et al., 2001; Norenzayan, Atran, Faulkner, & Schaller, 2006; Scalise Sugiyama, 2001); and

¹ As the term culture has many definitions, for the purpose of this paper, we define culture as: information (knowledge, beliefs, norms attitudes, and practices) transmitted between individuals as a function of social contact.

preferential avoidance of foods that are more likely to carry harmful pathogens (Fessler & Navarrete, 2003). In all of these domains, the authors propose that it is the relevance of the information to individuals, in particular fitness relevance, which may explain preferential attention and recollection of certain types of stimuli or information over others.

Learning about animals is another domain in which evolutionary theory would predict that content biases may be operating for several reasons. First, 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 (H. C. Barrett, 2005). Many kinds of knowledge might be useful for both avoiding predators and capturing prey, including knowledge of their behavior, habitats, diets, and more. Consistent with this, traditional foraging people typically have extensive and elaborate folkbiological knowledge, much of it oriented towards predation and hunting (Blurton-Jones & 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 fitness-relevant information over non-fitness relevant information in this domain – especially when there are tradeoffs in what can be retained from the incoming information stream.

Some experimental work has found evidence for content biases influencing how children learn about animals. Barrett and Broesch (in press) examined whether children,

age 4 and up, preferentially acquire and recall information about animal dangerousness, compared to other potentially learnable information about animals (H. C. Barrett & Broesch, in press). They reasoned that learning about danger presents particular challenges, because direct experience with animal dangerousness may be both rare and costly. For this reason, they proposed that children should be attuned to information about animal danger passed on by others, e.g. adults, through cultural transmission. And the amount of information necessary for a child to learn that an animal is dangerous might be quite minimal – perhaps even a single exposure. They tested this using parallel memory experiments with children in two cultural settings: urban Los Angeles and among the Shuar of Ecuador, an Amazonian hunter-horticulturalist society.

The main hypothesis of these experiments draws on theories put forth by Boyd and Richerson (1985) regarding social learning. First, 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 & Richerson, 1985). Second, because of the differences in the potential fitness costs to a child between knowing what an animal eats (low) and knowing if an animal is dangerous (high), content biases should favor the acquisition of danger knowledge over other types of knowledge. Related work on prepared learning provides a parallel line of theory and evidence, which motivates this work (Ohman 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 & Cook, 1988).

To test the hypothesis that human children exhibit prepared social learning about animal dangerousness, Shuar and American children participated in a flash-card memory task. They were presented with 16 unfamiliar animals and told the species name, diet, and whether it was dangerous or not. Immediately after presentation, and then again after a delay of one week, participants were asked what they remembered about each animal. Following training, in both short-term recall and after a delay of one week, children were above chance in recalling whether an animal was dangerous or not. In contrast, training did not improve memory for the diet or name of the animal, which remained at chance after training, as well as in a control condition. This demonstrates that a single event was sufficient to learn information regarding the ‘dangerousness’ of an animal and that this information was preferentially retained over other information about the species (H. C. Barrett & Broesch, in press).

Rationale and Hypotheses

The present study follows directly from the study by Barrett and Broesch regarding learning about novel animals. While we utilize similar methods, there are several key variations which allow us to examine the robustness of their findings. In

particular, we expand the age range to include older children and adults. This allows us to examine how the memory biases observed by Barrett and Broesch vary across the lifecourse. We also broaden the information that was presented to participants to include two more domains of knowledge: whether an animal is edible or poisonous, a domain that we hypothesized to be highly relevant for fitness, and where an animal lives, which we hypothesized would be of less fitness relevance.

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 of the 4 types of information (Danger, Poison, Habitat, and Diet) which are presented to the adults and older children in our sample.

Hypothesis 2(a)-Adults and older children will exhibit preferential recall of information in the domains of Danger and Poison. ; (b)-The magnitude of the content bias for fitness relevant information should be larger for children than for adults.

In general, we expect our findings to support and expand Barrett and Broesch's evidence for greater recall of information that is of higher relevance for fitness. 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 peaks 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. 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 & 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, therefore, could be quite different than how it is processed by, for example, 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 like these, predictions regarding content biases in adult foragers are not as

straightforward as for younger children. A goal of this study, then, is to empirically assess if 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 group.

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), while misidentifying a safe animal as dangerous would have much lower costs (avoiding a potential prey species). Error management considerations would predict that 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) (Haselton & Buss, 2000). 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 3 villages in the Fiji Islands. Informed consent from adults, parents of children, along with child assent was obtained from participants prior to testing. The adult sample was composed of 92 individuals, 52 from the island of Totoya and 40 from the island of Yasawa between the ages of 17 and 79 (Mean \pm SD=40.29 \pm 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 the Yasawa Island, 13 in the control group 17 in the experimental group. All children were between the ages of 7 and 14 (Mean \pm SD=10.5 \pm 1.93 Sex ratio F:M=.88).

Stimuli: Twenty animals were selected as exemplars, using a 5 X 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 4 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. 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. To simplify the implementation of the experiment, 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 presented with a picture of the first animal and told if it was dangerous (Danger), if it was 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.” 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 Delayed 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 are listed in Appendix Table 1. 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: While all species in this task were non-native to Fiji, it is not safe to assume that participants would respond as if guessing randomly if they were not given any information about the species. It is possible that background knowledge or visual information contained in the stimuli could cause 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, while 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 directly asked the questions regarding each species described above, but were not presented with any information about the species beforehand. 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, it is possible that due to visual information in the stimuli, or high levels of prior knowledge, poor design, or limited participant interest in the task, this may not have occurred. To evaluate this we compared the performance of the control group to the initial recall performance of the experimental group. By comparing differences in performance between the control group and 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 (i.e. dangerousness, poisonous, habitat, and diet). To evaluate this systematically, we utilized a generalized linear mixed effects model (GLMM) regression approach, using the lme4 package in R (Bates & Maechler, 2010; R Development Core Team, 2010). This statistical approach allows us to control for the non-independence of responses, (i.e. participants responded about multiple questions and multiple participants were responding on 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 on a question. As this is a binary variable, binomial regressions with logit link functions were used.

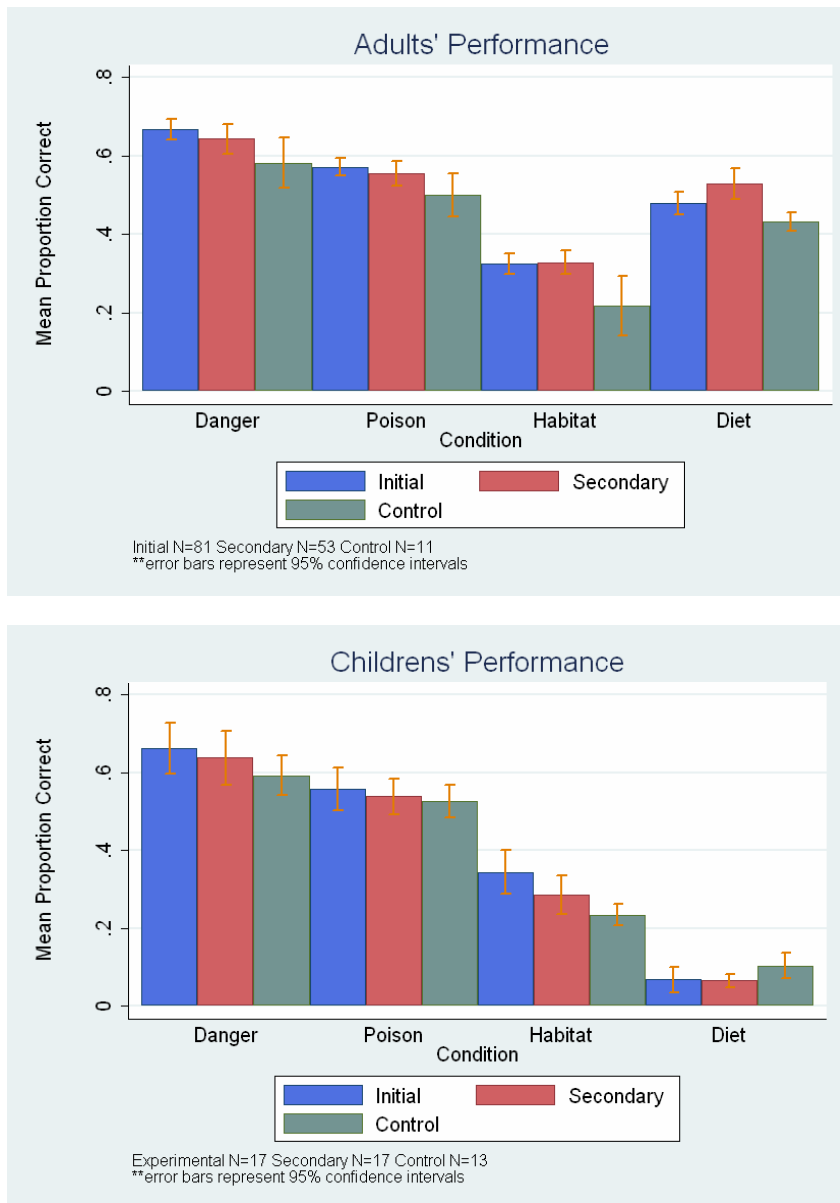
Baseline Likelihood of Responding Correctly

To evaluate our hypotheses related to single trial learning and content biases, it is first necessary to establish a baseline likelihood of responding correctly to the questions we asked. The parameter estimates for the Control Group in Table 1, which provide this

baseline estimate, are the odds ratio that an individual would respond correctly *without* being told any information about each animal, for each domain (i.e. Danger, Poison, Habitat, or Diet). Odds ratios greater than 1, for the Control Group estimates, indicate a greater than 50% probability of responding correctly. Significance testing indicates if the probability of responding correctly was different than 50%.

Both adults and children in the control group were equally likely to give a correct or incorrect answer about whether an animal is poisonous or dangerous. However, the magnitude of the coefficient for Danger, and the corresponding 95% confidence intervals, indicate that there may be slightly higher than 50% performance in that domain, although it was not statistically significant at conventional levels. As there were more than two possible choices for Diet and Habitat, it is not surprising that participants in the control group responded correctly less than 50% of the time. While the p-values of the parameter estimates for Diet and Habitat are of little practical significance, the magnitudes allow us to establish a baseline for each domain.

Figure 1- Comparing Performance for Control Group to Experimental Group



These graphs illustrate the difference in performance between the control group's and the experimental group's performance at both time points. While the experimental group performs better in all domains (except diet for children), not all of these differences are statistically significant at conventional levels. Further information on statistical significance is presented in Table 1.

Table 1- Likelihood of Responding Correctly to a Question

(a) Adults' Performance						(b) Childrens' 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	Control Group	Danger	1.58	0.87	2.88	0.13
	Poison	1.02	0.51	2.07	0.95		Poison	1.15	0.63	2.08	0.65
	Habitat	0.19	0.09	0.39	<.001		Habitat	0.21	0.11	0.39	<.001
	Diet	0.70	0.35	1.40	0.31		Diet	0.08	0.04	0.16	<.001
Initial Learning	Danger	1.80	1.19	2.72	0.006	Initial Learning	Danger	1.46	0.97	2.21	0.07
	Poison	1.52	1.03	2.25	0.037		Poison	1.18	0.79	1.77	0.42
	Habitat	1.95	1.26	3.01	0.003		Habitat	2.14	1.34	3.42	0.001
	Diet	1.26	0.85	1.85	0.25		Diet	0.60	0.32	1.12	0.11
Secondary Recall	Danger	0.92	0.74	1.13	0.42	Secondary Recall	Danger	0.88	0.62	1.25	0.46
	Poison	0.86	0.71	1.05	0.14		Poison	0.90	0.64	1.26	0.54
	Habitat	1.06	0.87	1.30	0.54		Habitat	0.68	0.46	0.99	0.047
	Diet	1.39	1.15	1.67	<.001		Diet	0.95	0.51	1.77	0.87

^a 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

^b Control Group-N=11, Experimental Group N=81

^a Question and Participant were included as random effects.
 Question-Variance 1.37 log-odds, SD 1.170 log-odds;
 Participant-Variance 0.06 log-odds, SD 0.24 log-odds

^b Control Group-N=13, Experimental Group N=17

These tables present the results of the GLMM models of participant performance. Random effect estimates for participants and questions are reported in the footnotes of each table. All parameter estimates are presented as odds ratios. The parameter estimates for the Control Group represent the odds of responding correctly about a question in a given domain. Values greater than 1 indicate an above 50% likelihood of responding correctly. 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 to the control group. Odds ratios greater than 1 for Initial Learning indicate an increase in performance compared to the performance of the Control Group. The parameter estimates for Secondary Recall represent the change in performance, in a given domain, from what was learned initially after ~1.5 weeks. Odds ratios less than 1 indicate a decrease in performance compared to the Initial Learning performance.

We now turn to separate tests of our initial predictions.

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

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

The odds ratios and p-values reported in the Initial Learning section of Table 1 represent the difference in performance compared to the control group. Odds ratios greater than one represent increased performance, and the corresponding p-values represent the statistical significance of that difference.

Adults in the experimental group performed significantly better than the control group on questions about Danger, Poison Habitat, and Diet, but the increase in performance for Diet was not statistically significant (see Initial Learning odds ratios in Table 1 and Figure 1). 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 to an adult in the control group.

When performance was evaluated by combining domains, adults did show significantly higher performance in the experimental group than in the control group. This was statistically evaluated by comparing a model with the coefficients for the

experimental group's initial performance included to one when it was excluded (ANOVA: $\text{Chi-Sq}_4=13.792$, $p=.008$).

Children showed significant increases in performance compared to the control group for Habitat, and non-significant increases in performance for Danger and Poison (see Initial Learning coefficients in Table 1 and Figure 1). Children in the experimental group performed worse than the control group on Diet questions, but this difference is not statistically significant.

When performance was evaluated as a whole, combining domains, children did show a significant increase in performance in the experimental group, which was statistically evaluated as described for the adults above (ANOVA: $\text{Chi-Sq}_4=16.335$, $p=.003$).

Hypothesis 2 (a) Adults and older children will exhibit preferential recall of information in the domains of Danger and Poison; (b) The magnitude of the content bias for fitness relevant information should be larger for children than for adults.

Summary of Findings: We find some evidence in support of Hypothesis 2a for children and no evidence for a recall bias for adults. There was no statistically significant evidence for increased short term recall of danger and poison information for adults or children. After ~1.5 weeks, adults do not show statistically significant greater recall of danger or poison information. Children between 7 and 14 years of age do show increased recall of danger and poison information after 1.5 weeks, but the difference is not significant at conventional levels. We observe a statistical trend toward an age by domain interaction

among children, with poorer performance in only the Danger domain as children get older. The presence of this age trend for Danger, and weak evidence for a recall bias after 1.5 weeks for children, but not adults, provides some support for Hypothesis 2b.

Hypothesis 2a can be evaluated at two separate time points in our study; once immediately following the presentation with information (Initial Learning in Table 1) and after 1.5 weeks after the information presentation (Secondary Recall in Table 1). While a comparison of the odds ratios and their confidence intervals in Table 1 can show if there are any significant differences in performance between domains, we also systematically evaluate this by running a series of GLM models where 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 interpretation of odds ratios presented in Table 1 below.

First, we examine if information was preferentially encoded and recalled on the test immediately following information presentation. For adults, the results from the series of GLMM models indicate that there are no statistically significant differences in how much performance increased between domains (results not show). However, based on the magnitudes of the odds ratios and their confidence intervals, it appears that adults were learning the most about Habitat, which was fairly similar to how much they were learning about Danger.

As discussed above, the odds ratios and p-values reported in the Initial Learning section of Table 1 represent the difference in performance after being presented with

information, compared to the control group. This reflects what was initially learned as a function of being told information about these species. Odds ratios greater than one represent increased performance, and the corresponding p-values represent the statistical significance of that difference. After being presented with information about the species, adults had 1.8 times to the odds of responding correctly to a question about if an animal was dangerous and 1.95 times the odds of correctly identifying a species habitat, compared to the control group. Adults were also learning about Poison, but this is somewhat less than what they were learning about Danger and Habitat. Learning about Diet trailed all other types of information.

We performed the same series of GLMM models where we varied the referent category for children as well, and again found no statistically significant evidence for more learning occurring for high fitness relevant information in the initial learning test. As children did not seem to be learning anything about Diet, it is not surprising that performance was lower in this domain when compared to others. Learning was significantly greater about Habitat than about Diet (GLMM- OR: 3.57 Z-statistic=3.367, $p = .001$), and about Danger than about Diet (GLMM- OR: 2.44 Z-statistic=2.467, $p = .014$). Learning about Poison was marginally significantly greater than about Diet, (GLMM- OR: 1.97 Z-statistic=1.887, $p = .059$), and it was significantly less than learning about Habitat (GLMM- OR: 0.55 Z-statistic=-2.068, $p = .039$). All other differences between domains are non-significant.

Examining the magnitudes of the odds ratios in Table 1 and their confidence intervals, we see a similar pattern to what was observed for adults. Learning was highest

for Habitat, followed by Danger (although the difference is greater than what is observed with adults). Learning about Poison was also lower than learning about Habitat and Diet, and lower than what is observed for adults. In sum, we find no evidence for a bias in the initial recall of danger and poison information over diet and habitat information for adults or children in this sample.

When we examine performance after one and a half weeks (see Secondary Recall in Table 1), we do find week evidence for increased retention of danger and poison information for older children, but not adults. To statistically evaluate this, we used the same series of GLMM with varied referent categories outlined above for the Initial Learning analysis. The odds ratios presented in the Secondary Recall section of Table 1 represent how much of the increase in performance from the initial learning test was retained after 1.5 weeks. Odds ratios equal to 1 indicate that participants remembered everything that they initially learned, and that the increase in performance compared to the control group was entirely retained. Odds ratios less than 1 indicate that participants forgot some of the information that they had initially learned.

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. The only domain with a significant difference in performance was Diet, where adults demonstrate an increase in their performance. When we make comparisons between domains by varying the referent category in a series of GLMM (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. More broadly, adults seem to remember most of what they have learned for Danger, Poison, and Habitat, indicating no evidence of a content bias between these domains of information.

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. The decrease in performance for Diet was very small, but because children don't show evidence of learning about Diet initially it is not surprising, as there was nothing for them to forget. When we sequentially vary the referent category in a series of GLMM, we find no statistically significant differences in retention between any of the domains.

In subsequent analysis, we include an age by domain interaction term in our GLM model for children presented in Table 1. We find a marginally significant interaction between age, centered to the mean, and Danger (GLMM- OR: .92 Z-statistic=-1.688, $p = .091$), indicating poorer performance on questions about danger as children got older. There were no other domains where the interaction terms are statistically significant; all other p -values $>.3$.

Broadly, these results indicate weak evidence in support of there being a content bias in children for preferential retention of danger and poison information compared to habitat information. Children had approximately 1.1 times the odds of correctly responding to a question about Danger and Poison on the initial learning test compared to

the secondary recall test, but they had 1.4 times the odds of correctly responding to a question about Habitat on the initial learning test compared to the secondary recall test. However, this difference in retention, between domains, is not statistically significant at conventional levels.

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 provides some support for a developmental trend which we explore further in the discussion.

Hypothesis 3-Participants should err on the side of caution in their attribution of dangerousness and poisonousness in both the experimental and control group.

Summary of Findings: We found strong evidence in support of this prediction.

Participants are significantly less likely to 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.

Table 2-Participant Attributions of Danger and Poison

(a) Adults

Group	Domain	Observed Proportion	Expected Proportion	<i>p</i>
Control Group	Danger	0.66	0.50	<.001
		0.66	0.45	<.001
Experimental Group	Poison	0.56	0.50	.034
	Danger	0.59	0.50	<.001
		0.59	0.45	<.001
Poison	0.63	0.50	<.001	

^a Control Group-N=11, Experimental Group N=81

^b Each Participant Responded to 20 Questions

(b) Children

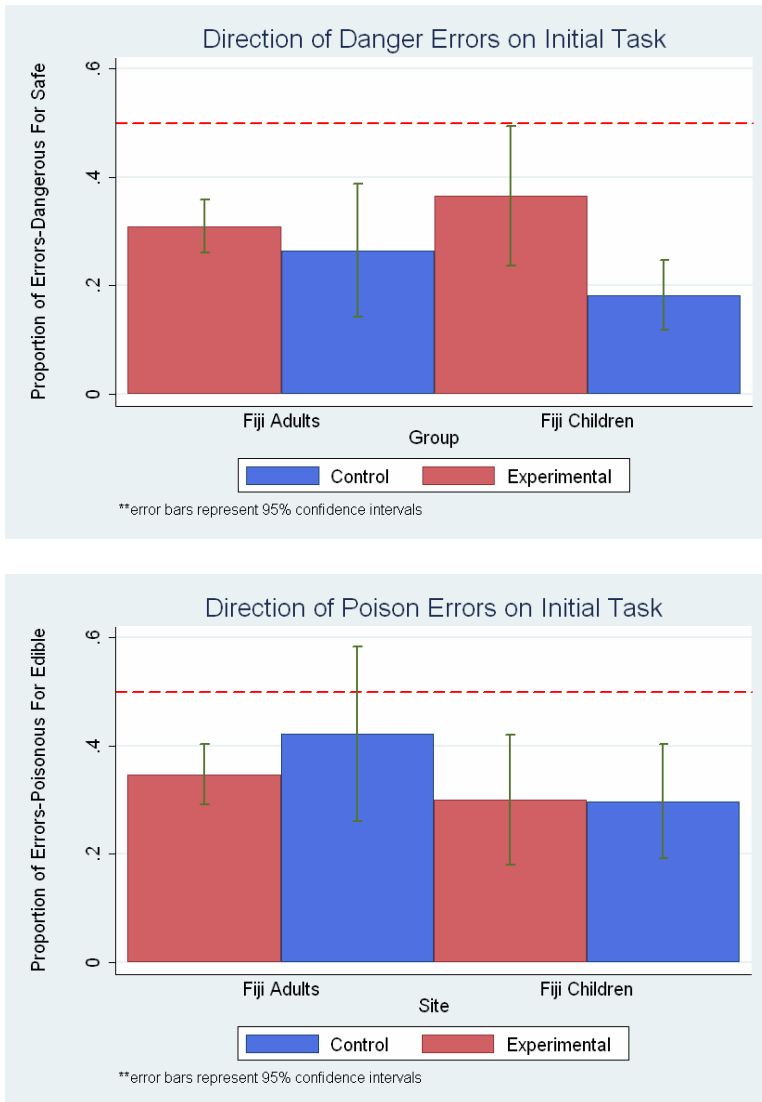
Group	Domain	Observed Proportion	Expected Proportion	<i>p</i>
Control Group	Danger	0.71	0.50	.005
		0.71	0.45	<.001
	Poison	0.68	0.50	<.001
Experimental Group	Danger	0.57	0.50	<.001
		0.57	0.45	<.001
	Poison	0.68	0.50	<.001

^a Control Group-N=13, Experimental Group N=17

^b Each Participant Responded to 20 Questions

This table presents 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 while exactly 50% were poisonous). All conditions, age groups, and domains exhibited a bias toward saying that animals were dangerous or poisonous (all $p < .05$).

Figure 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 red dashed line (.5) indicates what one would expect if participants were equally likely to mistake a dangerous animal as being safe, or a safe animal as being dangerous (and likewise for poison). The fact that the proportion of errors and their corresponding 95% confidence intervals for both adults and children in the control and experimental group are below this line indicates that they err on the side of caution (except adults in the control group for poison). That is, they are more likely to make the less fitness-costly mistake.

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 ($p < .05$ for all tests; see Table 2). For the Danger domain, we tested against expected probabilities of .45 (actual proportion of animals in stimuli that were dangerous), and .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 poisonous attribution, 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 where participants made errors in their danger or poison attributions to see if the direction of errors was in line with the predictions 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 matched predictions from error management theory (see Figure 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 an animal was poisonous or not; however, this was not significant for the adults in the control group.

The combined results of these analyses indicate that there is a general bias toward erring on the side of caution, which could be explained by a general bias toward saying that animals are dangerous or poisonous in the absence of other information (control group) or when participants are uncertain (experimental group-error bias).

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 with younger children; 2) There is no evidence for a content bias in the initial encoding of information, some evidence for a delayed recall bias 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 (in press), they suggest that the strong advantage for learning of danger over 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 error management theory (Haselton & Buss, 2000).

Our findings both replicate and strengthen many of the conclusions reached by Barrett and Broesch (in press). 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 was not included in the study by Barrett and Broesch (Poison and Habitat). We found strong evidence for some single trial learning without feedback for both adults and children in our sample. While 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 for children). We hypothesize that this is due to the increased attentional and memory capacities of the older children and adults in our sample, leading to reduced tradeoffs in the form of competition for attention and encoding than in the younger children studied by Barrett and Broesch.

While our examination of biases in the recall of information replicate some of the findings of Barrett and Broesch (in press), the general pattern that Barrett and Broesch found, that dangerousness information is strongly preferentially retained relative to diet and name information in 4 to 5 year old U.S. children and 4 to 11 year old Shuar children, only partly holds for Fijian children from 7 to 14, and not for Fijian adults. We also observe a statistical trend, which suggests that there may be a developmental trend which preferences the retention of danger information about animals when children are young, but diminishes with age.

In this study, we found no evidence for any preferential initial recall of information as a function of information type for adults or children, contrary to Barrett and Broesch's finding of a bias for learning about danger information. In our study, the

difference between domains in the amount of learning that occurred are not statistically significant, nor was the magnitude of the coefficients suggestive of preferential learning in the domains of Danger and Poison over Diet and Habitat. This leads us to conclude that within the domains tested, the type of information has little effect on encoding and immediate recall of information in older children and adults.

When examining the delayed recall of information in children age 7 and up, we observe weak evidence for higher retention in the domains of Danger and Poison, which we hypothesized to be of higher relevance for fitness, replicating some of Barrett and Broesch's findings. There is a significant decrease in performance in Habitat, while decreases in performance in Danger and Poison are smaller and not statistically significant. However, 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 between retention in domains that we hypothesized to be of higher fitness relevance compared to less fitness relevant domains. Children learned the most about Habitat followed by Danger, but then forgot more about Habitat than Danger and Poison; however, when examining both the initial and the delayed recall together, children exhibit about equal increases in performance in Danger and Habitat after 1.5 weeks compared to the control group. In other words, while there may be some evidence of a content bias for higher retention of fitness relevant information in children, children exhibit similar increases in performance in Habitat and Danger on the whole after 1.5 weeks.

Our results indicate no evidence for any biases towards a preferential retention of particular categories of information in adults. Degradation is relatively small in all

domains, indicating that adults remember most of what they learned initially. The observed increase in performance for Diet is hard 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 where the participants that 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 that 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 that we would not expect to see the same pattern if the study was replicated.

While we can make no definitive conclusions regarding why we observed a developmental trend in learning biases, 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 we predicted danger information and poisonousness information to be particularly fitness-relevant for children and adults, all of the kinds of information we presented are the kinds of information used by adult foragers to capture and avoid animals. For example, knowing an animal's habitat tells you where to look for it, and knowing its diet tells you how to bait a trap or a hook, or under which fruiting trees you might wait to catch it.

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 (H. C. 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 & 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. This finding matches with predictions from error management theory (Haselton & Buss, 2000), and 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 when dangerous and poisonous animals are fairly common (which they are). 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

There are several limitations to this study that are important to acknowledge. First, the study is limited for making generalizations outside of this sample population (Fijian village). It is possible that the types of biases we have documented, such as the safe / dangerous error bias is not present in other cultural groups because it is a culturally acquired bias. However, given that Barrett and Broesch (in press) present very similar results with both U.S. children and Shuar children, there is support for the hypothesis that this may be an evolved feature of human memory and judgment systems.

Second, our sample is of limited size (especially for children) which minimizes our statistical power for drawing conclusions. While we have distinguished between results that are statistically significant at the conventional level of $p < .05$ throughout this paper, some readers may be less inclined to support our interpretation of differences where $p > .05$. 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 & Altman, 1986). We believe there is merit in both the use of 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 poisonous species. Given the high fitness consequences for encountering a dangerous animal or consuming a poisonous animal, cultural evolutionary theory would predict that learning about animals would be a domain where content biases may privilege the retention of fitness relevant information about animals over other kinds of information. This study replicates some of the results observed by Barrett and Broesch (in press) and presents evidence in support of this hypotheses, 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. Overall, this work suggests that future work should focus on theorizing and studying the emergence and disappearance of content biases over the lifecourse.

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Appendix Table 1-Forced Choice Options

Habitat Forced Choice Options		Diet Forced Choice Options	
English	Fijian	English	Fijian
It lives in forests in trees	E bula ena vunikau e loma ni veikau	It eats only other animals and fish	E kani ira ga na manumanu kei na ika
It lives in forests on ground	E bula e dela ni qele ena loma ni veikau	It eats plant matter (fruit, leaves, seeds) and insects	E kania na vei tiki ni kau(vua-ni-kau, drau-ni-kau, sore-ni-kau) kei na manumanu somidi lalai
It lives in forests on trees and on the ground	E bula ena dela ni qele kei na vunikau ena loma ni veikau	It eats only other animals	E kani ira ga e so tale na manumanu
It lives in in open areas	E bula ena vanua galala	It eats other fish and small molusks	E kani ira eso tale na ika kei na vivili
It lives in in marshy areas	E bula ena vanua lolobo	It eats plant matter (fruit, leaves, seeds), animals, and insects	E kania na vei tiki ni kau(vua-ni-kau, drau-ni-kau, sore-ni-kau), manumanu, kei na manumanu somidi lalai
It lives in on the edge of forests	E bula ena tutu ni veikau		
It lives in in the ocean in deep water	E bula ena waitui titobu	It eats only insects	E kania ga na manumanu somidi lalai
It lives in in the ocean in shallow water	E bula ena waitui mamatia	It eats the flesh of other animals without killing it	E dau kania na lewe ni so tale na manumanu ia e sega ga ni vakamatei ira
It lives in in freshwater lakes	E bula ena waidrano		
It lives in in fresh water streams	E bula ena wai drodro.		