CHILD DEVELOPMENT

Child Development, May/June 2016, Volume 87, Number 3, Pages 770–781

Mapping the Cultural Learnability Landscape of Danger

H. Clark Barrett and Christopher D. Peterson
UCLA

Willem E. Frankenhuis
Radboud University Nijmegen

Cultural transmission is often viewed as a domain-general process. However, a growing literature suggests that learnability is influenced by content and context. The idea of a learnability landscape is introduced as a way of representing the effects of interacting factors on how easily information is acquired. Extending prior work (Barrett & Broesch, 2012), learnability of danger and other properties is compared for animals, artifacts, and foods in the urban American children (ages 4–5) and in the Shuar children in Ecuador (ages 4–9). There is an advantage for acquiring danger information that is strongest for animals and weakest for artifacts in both populations, with culture-specific variations. The potential of learnability landscapes for assessing biological and cultural influences on cultural transmission is discussed.

In the social sciences, it is common to consider evolutionary and cultural explanations for phenomena to be in opposition: To say that a trait or behavior is culturally shaped means that it is not the result of the evolutionary process, and vice versa. However, an emerging consensus in the evolutionary social sciences is that evolutionary and cultural explanations are compatible and even synergistic. The reason is that culture, too, is a product of the evolutionary process. Not all organisms are cultural; to the extent that cultural transmission exists in a species, it must be enabled by evolved mechanisms specialized for cultural transmission and cultural learning. Also, culture itself evolves. This means that cultural phenomena are the outcomes of processes of cultural evolution. Moreover, in the culture–gene coevolutionary process, the products of cultural evolution feed back on the species that created them, altering their fitness landscapes and therefore the course of subsequent evolution (Barrett, 2015; Boyd & Richerson, 1985; Laland, Odling-Smee, & Feldman, 2000; Mesoudi, 2011; Tooby & Cosmides, 1992).

These considerations urge a rethinking of the notion of culture as a purely general-purpose process. Just as the fitness landscape of a species is almost never perfectly flat—not all genotypes and phenotypes have identical fitness or identical evolutionary dynamics—neither is the cultural landscape likely to be. Instead, cultural variants may differ in their learnability, their transmissibility, and their subsequent dynamics in populations of cultural learners. A growing body of theoretical and empirical work has documented ways in which both the content of information and the context in which it is transmitted and learned can influence how easily learners retain information. Developmental and evolutionary psychologists have argued that there are likely to be many domain-specific effects in learning and development, driven by learning mechanisms that are organized around evolved domains including physical objects, intentional agents, kinship, social exchange, food, spatial navigation, and predation (Carey, 2009; Frankenhuis & Barrett, 2013; Gelman & Legare, 2011; Lieberman, Tooby, & Cosmides, 2007; New, Krasnow, Truxaw, & Gaulin, 2007; Tooby & Cosmides, 1992). Empirically, there exist a host of demonstrations of domain-specific effects in learning. These include increased attention to and learnability of information about danger, threat, and negative events (Baltazar, Shutts, & Kinzler, 2012; Barrett & Broesch, 2012; Fessler, Pisor, & Navarrete, 2014; Frankenhuis & de Weerth, 2013; LoBue & Rakison, 2013; Rozin & Royzman, 2001; Wertz & Wynn, 2014a). There is evidence for specialized learning processes for many evolutionarily important categories of information including foods, artifacts, gossip, and the attributes of social group members (Klein, Cosmides, Tooby, & Chance, 2002; Krasnow et al.,

---

Correspondence concerning this article should be addressed to H. Clark Barrett, Department of Anthropology and Center for Behavior, Evolution, and Culture, 341 Haines Hall, UCLA, Los Angeles, CA, 90095-1553, USA. Electronic mail may be sent to barrett@anthro.ucla.edu.

0009-3920/2016/8703-0013
DOI: 10.1111/cdev.12495

2011; Mesoudi, Whiten, & Dunbar, 2006; New et al., 2007; Shutts, Kinzler, McKee, & Spelke, 2009; Wertz & Wynn, 2014b). All of these suggest that there are interactions between the content of information and how easily it is learned.

Culture–gene coevolution theorists have produced a diverse array of models examining how the transmissibility of information is likely to be shaped by its content, sometimes known as *content biases*, as well as *context biases* such as prestige bias (bias to acquire information from high-prestige individuals) and conformity bias (bias to learn the most common information variant in a population; Boyd & Richerson, 1985; Henrich & McElreath, 2003; Mesoudi, 2011). According to these models, content and context biases are not mutually exclusive; indeed, they are expected to operate in parallel, leading to interactions between what information is about and the context in which it is transmitted and acquired.

Learnability Landscapes

Here, we introduce the concept of a learnability landscape as a means of conceptualizing potential variation in the learnability of information as a function of the ways it might vary in both content and context of acquisition (Figure 1). This conceptualization is analogous to the notion of an adaptive landscape in biology, in which the horizontal dimensions correspond to dimensions of genetic variation, and the vertical dimension to the fitness of a particular genotype. In learnability landscapes, on the other hand, the horizontal dimensions correspond to dimensions along which information can vary. These include variations in information content—what the information is about—as well as in the context of acquisition. Context can include not only local properties of an informational variant, such as its commonness (important in conformity bias), but also states of the learner and the transmitter (e.g., age, culture, status, mood, and other individual differences, including differences in developmental environment that might shape individuals' processing of information). The vertical dimension, or height, at any point in the landscape corresponds to the learnability of the information for the specific combination of parameter values at that point. Thus, peaks on the landscape represent combinations of features that make information easy to acquire, and valleys are areas of low learnability, where information is more difficult to acquire (e.g., requiring more effort, attention, or exposure to learn).

In principle, learnability landscapes could be flat or curved at different points on their surfaces. Relative flatness corresponds to a notion of cultural "equipotentiality"; that is, different cultural variants are equally easy to learn and transmit (Barrett & Broesch, 2012; Sperber & Hirschfeld, 2004). The notion of equipotentiality traces back to behaviorist learning theory and originally referred to the idea that any two stimuli are equally easy to associate. Early studies of learning of fear and disgust showed that equipotentiality does not hold across all stimuli, suggesting that learnability landscapes

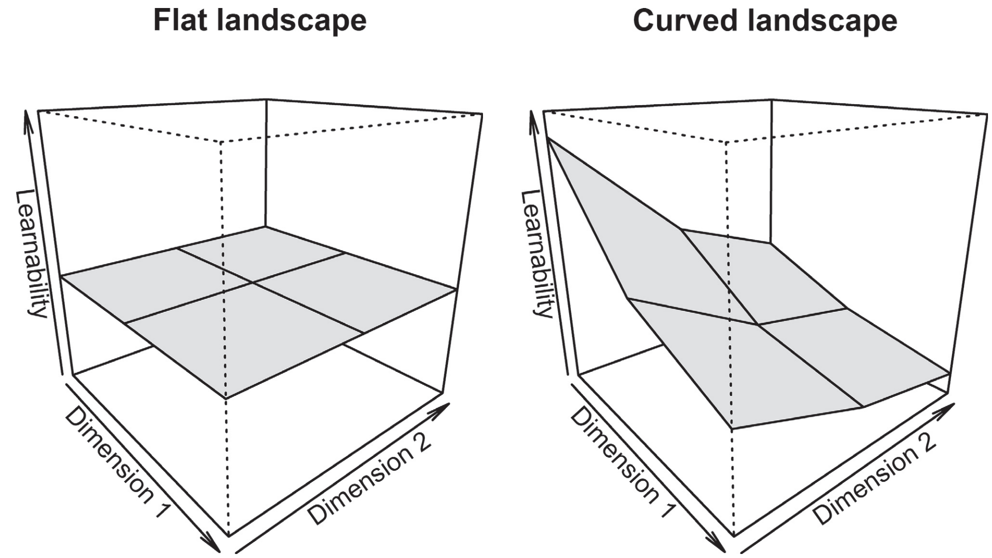

Figure 1. Learnability landscapes.

are not entirely flat (Garcia & Koelling, 1966; Öhman, Fredrikson, Hugdahl, & Rimmo, 1976). In humans, a variety of content biases have been documented in learning of danger and disgust, in infancy through adulthood (Barrett & Broesch, 2012; Fessler et al., 2014; LoBue & Rakison, 2013; Rozin & Fallon, 1987; Rozin & Royzman, 2001; Wertz & Wynn, 2014a).

It seems likely, then, that learnability landscapes will often be curved rather than flat. However, our current picture of the entire geography of cultural and individual learning remains piecemeal. There are many demonstrations of both content and context effects in learning, but each of these provides just a snapshot of a particular point in the learnability landscape. Although this work has been extremely important and influential in establishing a catalog of diverse learning effects, we suggest that a next step will be to extend these snapshots to cover ever-widening portions of the learnability landscape, with the aim of mapping its complex topography of interacting factors. This can be done by mapping specific neighborhoods on the learnability landscape, starting at a point in the landscape defined by a particular combination of information parameters, and then systematically varying those parameters to see how the learnability of the information changes. To do this, it is useful to employ a standardized methodology within which parameters of information (e.g., content, context) are systematically manipulated, in order to compare learnability effect sizes in a standardized way at different points in the landscape.

This is the approach we adopt here: We start with a measure of the learnability of information about animal dangerousness established by Barrett and Broesch (2012), and then systematically vary both the category of object (animals, foods, artifacts) and the type of property being learned (danger, location in the environment, seasonality, etc.) to map the shape of the learnability landscape around this point. Pursuant to the goal of quantifying learnability effects, we use a data modeling approach that allows us to find best estimates of the effect sizes of the factors we vary. Crucially, we use binary items to measure learnability in all cases (e.g., safe vs. dangerous, herbivore vs. carnivore), thereby keeping information complexity constant and providing a common metric of learnability (use of binary items is not necessary for the study of learnability landscapes, but is one useful means of insuring equal information complexity across conditions). This allows us to quantify the steepness or flatness of the learnability landscape in different directions in parameter space. Although this study measures a modest portion of the danger learnability landscape, it is intended as an initial case study in the mapping of learnability topologies, which can then be extended to other domains and regions of the overall learnability landscape.

Cultural Learning of Danger as a Case Study

Building on earlier work on the social learning of danger, Barrett and Broesch (2012) developed a flashcard task to measure the learnability of information about animals via cultural transmission, as a function of information content. Models of social learning identify a variety of factors that can lead to information being rapidly acquired through social, as opposed to individual, learning (Boyd & Richerson, 1985; Feldman, Aoki, & Kumm, 1996). For acquisition of danger information, two factors are particularly important. First, for danger, the costs of individual learning are high relative to socially learning the same information—for example, learning that an animal is dangerous through being injured, as opposed to being told. Second, in the case of many kinds of dangers, the relevant information is available from more knowledgeable conspecifics (e.g., adults). Together, these factors select for attention to others as a source of information about local danger, and rapid learning from them. Mineka and colleagues' studies of the social learning of fear in rhesus macaques support this model: Naïve laboratory-reared juveniles rapidly acquire fear of snakes through social referencing of the fear expressions of adults (Cook & Mineka, 1989; Mineka, Davidson, Cook, & Keir, 1984). Based on this logic, Barrett and Broesch conjectured that children might learn rapidly whether an animal is dangerous merely by being told this information by adults (see also LoBue & Rakison, 2013, for additional evidence of rapid learning of fear-relevant stimuli in human children).

To test this hypothesis, Barrett and Broesch (2012) developed a simple flashcard task that could be easily transported across cultures. In this task, children ages 4–8 were shown laminated flashcards of unfamiliar animals that were pretested in both populations to be unfamiliar to most children in the tested age range. The animals included species unfamiliar to participants, such as pangolins and kinkajous (see Figure 2 in the Method section below, for sample photos; see Barrett & Broesch, 2012, for details on stimulus preparation).

The flashcards were shuffled to randomize their order before presentation. For each, the child was told several properties, in counterbalanced order across property types, while being shown the photo for inspection: the animal's name, whether it was safe or dangerous, and whether it ate animals or plants (prior to the study, these properties were pretested by asking each child to name an animal with each of the properties). At the end of the deck, the cards were shuffled and shown to the child again, and the child was asked to recall each of the properties for each of the animals. This immediate test session was called the "Test" phase. One week later, the child was tested on the same flashcards; this was called "Retest." In addition, a subset of the children was randomly assigned to a control condition in which the same questions were asked about the animals, but without a training session. This control ensured that the properties of these unfamiliar animals could not be guessed from the cards alone.

Using this method, Barrett and Broesch (2012) tested children in two populations: the urban American children from day cares in Los Angeles (age range 4–5) and children among the Shuar, an indigenous Amazonian society in southeastern Ecuador. Comparing Shuar and American children on this task was particularly relevant for the hypothesis that there is an evolved prepared learning effect for danger, because actual exposure to animal dangers is radically different for children growing up in the two populations; Shuar children encounter more dangerous animals and are at greater risk of injury from them. The results showed a learnability advantage for danger information in both populations, consistent with a prepared learning effect for danger that extends across cultures. The size of the effect was slightly larger in the Shuar children than in the American children, consistent with at least two possibilities: developmental calibration of the learning effect due to greater presence of dangerous animals among the Shuar or an age effect (the Shuar sample included a broader age range; see the Discussion section). The danger learning advantage extended to the Retest session 1 week later. Moreover, learning of animal names and animal diets was poor, with performance near chance at Test and Retest (see animal data in Figures 3 and 4 in the Results section).

Here, we use Barrett and Broesch's animal data as a baseline (animal data in Figures 3 and 4), and extend their flashcard task to look at two additional categories of object—food and artifacts—as well as additional properties including location, seasonality, and other features.

Danger Learning for Food and Artifacts

There are several reasons why examining danger learning for foods and artifacts is of theoretical and empirical importance, and why comparisons between Shuar and American children in these domains are illuminating. From an evolutionary perspective, both foods and artifacts are types of object with which humans have interacted over long stretches of evolutionary time—though our evolutionary history of interaction with food is of course substantially longer. Consistent with this, there is evidence for specialized learning for foods (Cashdan, 1994; Shutts et al., 2009; Wertz & Wynn, 2014b) and artifacts, especially tools (Casler & Kelemen, 2005; DiYanni & Kelemen, 2008; Kemler Nelson, Russell, Duke, & Jones, 2000). In addition, there is likely to be an effect of danger on learning in both domains, but there are reasons to expect the exact nature and context of danger effects to differ across the domains. In the case of food, the most relevant danger is, of course, contagion, with its concomitant emotional response of disgust (Curtis, Aunger, & Rabie, 2004). Indeed, prior work indicates that disgust for potentially contagion-carrying foods can be rapidly acquired (Rozin & Fallon, 1987). For this reason, the specific kind of danger from food that we focus on is the ability to make the child sick. In the case of artifacts, on the other hand, the most relevant danger is the potential for artifacts to cause injury, which is the source of danger we focus on in our task.

As was the case with animals, differences between the study populations we examine here, Shuar and American, are of interest with respect to both foods and artifacts. Food is a domain that is notoriously prone to cultural variation in preferences, often in ways that can trump danger per se (e.g., some cultures enjoy foods that others would regard as disgusting and that can even be dangerous, such as toxic fish). In order to avoid culturally marked foods, we specifically used natural, unmodified foods such as nuts and fruits, but even here, one might expect differences in the ways that Shuar and American children learn about these foods (e.g., Shuar children might be more cautious about novel fruits, as these could be more often encountered in a wild context than for urban Angeleno children; Wertz & Wynn, 2014a). In addition, properties such as location and seasonality, which we examine here, could have different importance for children in foraging and nonforaging cultures.

The question of possible prepared or specialized learning for artifacts is an interesting one because

Figure 2. Sample flashcard images.

artifacts, such as stone tools and hunting weapons, have played an important role in recent human evolution. Consistent with this, there is a large literature on learning about artifacts, including the role of functional information in facilitating learning (Kemler Nelson et al., 2000). However, there are also reasons to expect differences between Shuar and American children in learning about artifacts. For one, Shuar children grow up in more "technologically sparse" conditions, with fewer artifact types, and fewer high-tech manufactured artifacts such as elevators and automobiles (German & Barrett, 2005). Moreover, the dangers posed by particular kinds of artifacts, and parental warnings about them, are likely to differ between the two cultures, with American parents warning their children about toaster ovens and hot stoves, while Shuar parents, like parents in many traditional societies, typically have a more laissez-faire attitude about potentially dangerous objects like knives.

In each of these cases, there are multiple possibilities for how learnability effects will vary, or be similar, across cultures, domains, and property types. For this reason, we are primarily concerned with measuring and quantifying the nature of these effects, so we adopt a data modeling approach using general linear models with model comparison to obtain the best fit estimate for the effect sizes of the different factors we are investigating.

Method

Socioeconomic and Cultural Characteristics of Sample Populations

We collected data from children in two study populations: U.S. children in urban West Los Angeles ($N = 69$), and Ecuadorian children, primarily Shuar, from rural southeastern Ecuador ($N = 67$; see Appendix S1 for sample sizes and demographic characteristics of samples). These are the same populations sampled by Barrett and Broesch (2012), using parallel methods, and we include data from the original participants recruited for the animal study by Barrett and Broesch, as well as four new groups of participants: two groups of American children and two groups of Shuar children, one group of each for the foods study and the other group of each for artifacts.

The Shuar are an indigenous Amazonian society in southeastern Ecuador. The children in our sample live in small rural villages where their parents practice a mix of traditional subsistence (hunting, fishing, small-scale horticulture) and wage labor (schoolteachers, day labor, local government). There is bilingual education and access to government-sponsored health clinics. Most Shuar children have substantial experience with local animals and plants, are allowed to handle artifacts including hunting and cooking implements, and participate in food gathering and preparation.

Our U.S. sample was composed primarily of middle-class American children from West Los Angeles, recruited through day-care centers in the West Los Angeles area. Unlike Shuar children, most of the L.A. children have less experience with rural environments, and encounters with animals are mostly through pets, zoos, and media. Attitudes of middle-class American parents toward dangers differ from those of most Shuar parents, with Americans offering more explicit warnings about dangers such as dangerous artifacts, and taking greater measures to prevent risk of illness and injury. Thus, in addition to differences in wealth and access to resources, children from the two sample populations differ in type and degree of interaction with animals, plants, and artifacts, as well as cultural attitudes toward them.

Procedures

The flashcard procedure was similar across all studies, with some exceptions. Here, in the main text we describe common elements of the procedure across the studies. Variations between the animals, foods, and artifacts studies are described in detail in Appendix S1.

Across all studies, children were first asked if they were willing to participate, and if so, were brought to a quiet area of their day care or school for testing. The experimenter told the participant that he would show her a series of pictures of things she might not have seen before, and would tell her something about each one (there were both male and female experimenters and participants; gender terms here are for illustration purposes). The experimenter said that they would then look at the pictures again to see what the child remembered. If the participant agreed, the procedure began.

First, a series of warm-up questions were asked to ensure that the child was familiar with the properties being presented in the task. For example, for animal danger the child was asked, “Did you know that some animals are dangerous and other animals are safe? Can you give me an example of a dangerous animal? How about a safe animal?” In cases where the child did not provide a correct response or any response, the experimenter engaged in a discussion with the child until it was clear she understood the term in question (e.g., dangerous, safe). All U.S. children were interviewed in English, and Shuar children were interviewed in Spanish by Spanish-fluent experimenters (all participants spoke Spanish as well as, in the case of ethnic Shuar children, Shuar). The experimenters were either the authors or undergraduate research assistants.

Following the warm-up questions, the deck of flashcards was shuffled: 16 laminated cards, approximately 8 in. by 5 in. in size, with color photos of objects in the study category (animals, foods, or artifacts). Examples of images on the flashcards are shown in Figure 2.

Objects were preselected as likely to be novel to both the U.S. and the Shuar children, and the same cards/objects were used for both populations (see below for details on stimulus selection). After shuffling, the child was presented with each card, one at a time, and the experimenter read the test properties for that item off the back of the card. In the animals study, these were name and two other properties, danger and diet; in the foods and artifacts studies, three binary properties were used, including danger (safe or dangerous) and two others, as described below. Order of property presentation was counterbalanced. At the time of presentation, children were told each property, with a pause of 1–2 s, and allowed to inspect the card, upon which it was moved to the back of the deck and the next card presented. This continued through the 16 cards.

The Test session began immediately after initial stimulus presentation. The experimenter said, “Now let’s look through the cards again and you can tell me what you remember for each one.” The experimenter shuffled the deck, for a new random order, and proceeded to present each card, asking the child about each property in turn. For the binary properties both options were presented, for example, “Is this animal safe, or dangerous?” (order counterbalanced across cards). If the child was not sure, she was asked to guess, so that the recall test was a forced-choice task (for the names in the animals study, it was a free recall task). Crucially, no feedback on the correctness of the child’s response was given. At the end of the session, the child was told that the experimenter would return in a week to look at the cards again.

After 1 week, the Retest session occurred, and was identical in format to the Test session. The child was shown the 16 cards again, in a new shuffled order, and asked a forced-choice question for each property of each card. Following the Retest session, the child was thanked for her participation.

The properties examined varied across the animal, food, and artifact studies. The animal study examined dangerousness (“Could it hurt you or not?”) and diet (“Does it eat plants or animals?”). For foods, we examined dangerousness (“Could it make you sick?”) and two other properties, which varied slightly for Shuar and U.S. children based on pretesting. One type of property, labeled “feature” in the Results section below, was spring versus fall for the U.S. participants, and rainy season versus dry season for the Shuar participants. Another was “location,” which was mountains versus jungle for the U.S. participants, and growing in trees versus on the ground for the Shuar participants. In the artifacts study, we examined dangerousness (“Could it hurt you if you handled it?”) and two other properties. The “feature” property was breakable versus nonbreakable for the U.S. participants, and expensive versus cheap for the Shuar participants. The “location” property was used indoors versus used outdoors for the U.S. participants, and used in the kitchen versus used in the garden for the Shuar participants. Further details of similarities and variation in methods across the three studies are provided in Appendix S1. All data analyzed in this article are available in Data S1.

Results

Figures 3 and 4 display the results in two formats. In Figure 3, results are shown in the form of learnability landscapes, with learnability (recall success) shown on the vertical axis. Figure 4 displays the same data in conventional format.

We analyzed results using a series of general linear mixed models (GLMM) with logit link functions using the glmmADMB package (version 0.8.0; Fournier et al., 2012) for R (version 3.1.0; R Core Team, 2014). We employed a model comparison approach using Akaike's information criterion (AIC) to compare fit across models with different combinations of parameters. The full list of models compared can be found in Appendix S1. Table 1 summarizes the parameter estimates of the best fit model. Several models were nearly tied in their AIC scores, suggest-

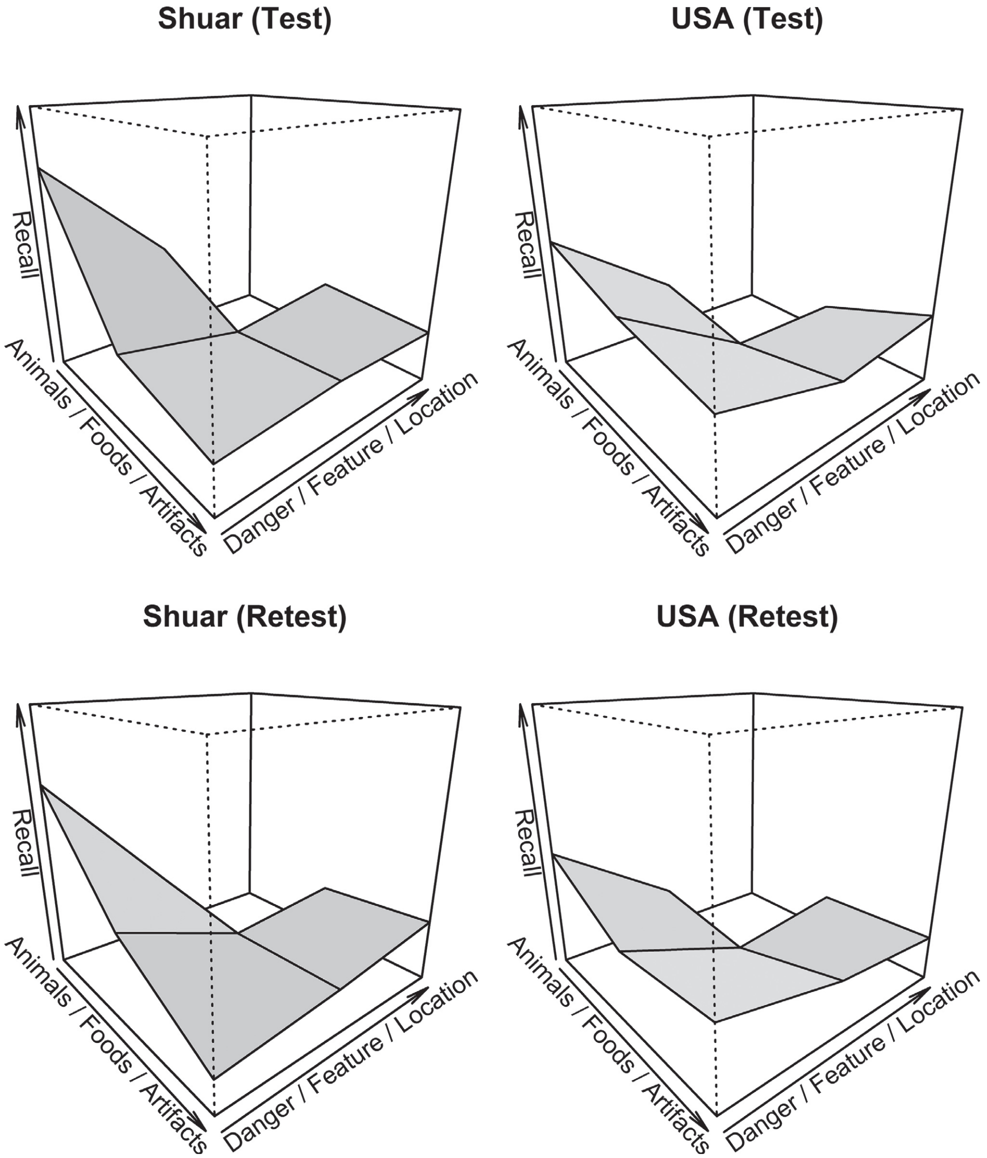

Figure 3. Learnability landscapes for Shuar and American children at Test and Retest. The vertical access shows recall success ("recall"; minimum = 0.4, maximum = 1.0). Horizontal axes show domain (animals, foods, artifacts) and property (danger, feature, location), respectively.

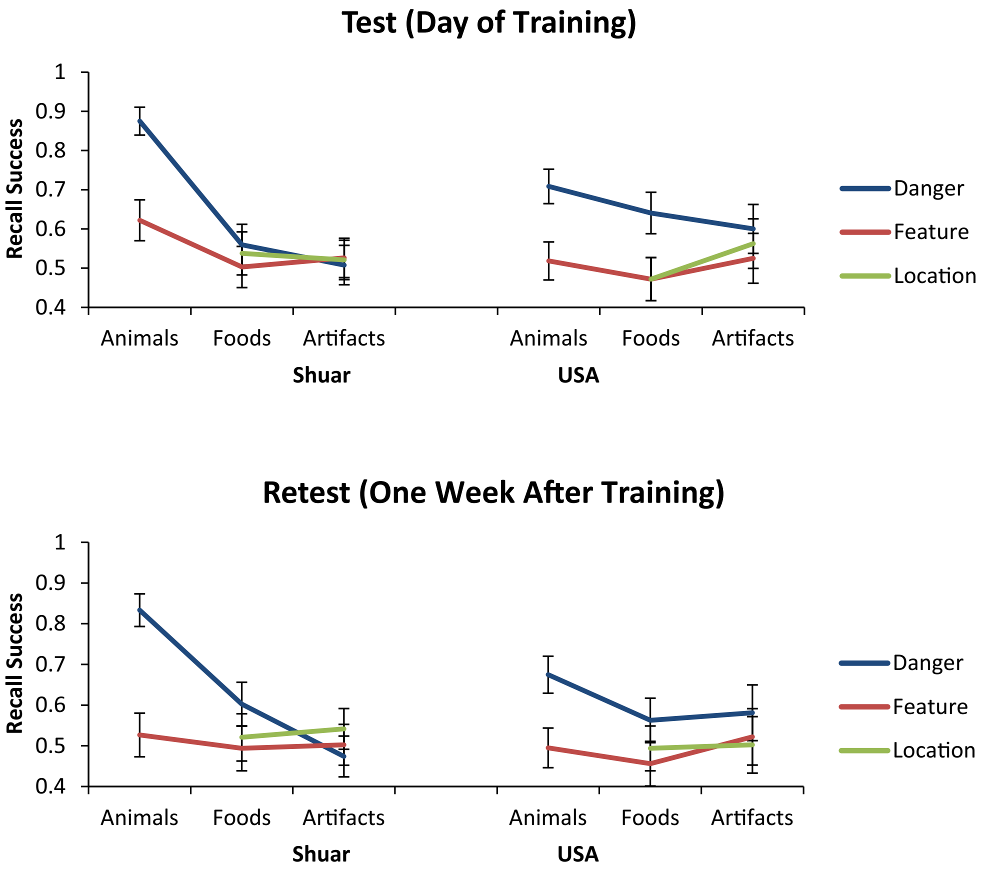

Figure 4. Recall performance at Test and Retest. Error bars are ± 95% confidence interval.

Table 1
Parameters of Best Fit General Linear Mixed Model

Factor	Estimate	*SE*	*z*	Pr(>|*z*|)
Fixed factors (reference factors: Domain [foods], Property [location])				
Intercept	0.065	0.075	0.87	0.38
Domain (animals)	0.54	0.085	6.32	2.7e−10***
Domain (artifacts)	0.0062	0.083	0.07	0.94
Property (danger)	0.31	0.055	5.70	1.2e−08***
Property (feature)	−0.21	0.055	−3.85	0.00012***
	Variance	*SD*		
Random factors				
Participant	0.095	0.31		
Test/Retest	0.0023	0.048		

***$p < .001$.

ing that some of the parameters with very small variance estimates had negligible effects on the overall model fit (see Appendix S1 for details).

The best fit model confirms the patterns visible in Figures 3 and 4. First, there was a large and significant effect of domain, with animals being the most memorable category overall. Second, there was a large and significant effect of property type, with danger being the most memorable. In addition, there was a small but nonsignificant effect of Test versus Retest, consistent with single-trial learning and immediate encoding of information into long-term memory. The best fit model did not include an effect of sex or population, indicating no overall memory advantage for the Shuar over the U.S. children in this region of learnability space.

For technical reasons (rank deficiency) we were unable to model the interaction between domain and property type as fixed factors in the best fit model, but we report an estimate of their interaction as random factors in the Table S2.

In addition to these estimates of the effects of our experimental parameters on variation in learnability, the following parameter combinations led to recall performance that was significantly above chance at the $p < .05$ level (z test, two-tailed). For Shuar participants, recall was above chance for animal danger at Test and Retest, for animal diet at Test, and for food danger at Test and Retest. For the U.S. participants, recall was above chance for animal danger at Test and Retest, for artifact danger at Test and Retest, and for food danger at Test and Retest (see Table S3 for a complete list of means and 95% confidence intervals for all conditions). Thus, overall, danger was the most memorable property type across the domains for both populations, with the exception of artifact danger for the Shuar, possible reasons for which we discuss below. Interestingly, none of the other property types were statistically above chance, with the exception of diet for the Shuar.

Discussion

Our results provide a preliminary map of one region of the cultural learnability landscape of danger, as measured by a flashcard teaching task administered to children by adults. Using this method, we measured learnability of danger and several other properties for animals, foods, and artifacts, in two disparate cultures, the Shuar of Amazonian Ecuador and the U.S. children in urban Los Angeles. We found that in this region of learnability space, both category type (domain) and property type (danger, location, etc.) significantly influence the learnability of information about an object, with animals having the largest domain effect and danger the largest property effect for the conditions tested.

In this region of learnability space we found only small cultural differences in the learnability of the information presented. Given the cultural and environmental differences experienced by Shuar and American children (detailed above), one might have expected greater cultural differences between the populations. In this case, the similarities in overall shape of the learnability landscapes in the two populations suggests that evolved prepared learning of danger plays a large role compared to local calibration of learning to the actual, ontogenetically experienced danger environment of the child. While there is evidence consistent with local environmental calibration of the learning effect, which we discuss in the next paragraph, the ordering of the learnability effects is similar across cultures: Among the item types, danger is most easily learned, and among the object categories, danger is most easily learned for animals. Given that the American children face low risk of injury from animals and much higher risk of injury from artifacts, one might have expected this order to be reversed, if it were strongly calibrated by the ontogenetic environment of the child. The fact that information about animal danger is most learnable across both the Shuar and American children suggests that the evolutionary process, acting over long periods of time, has calibrated children's learning priors to be most receptive to information about animal dangerousness.

Against the backdrop of overall similarity in learnability landscapes across cultures, there were some modest but significant differences that make sense in light of the population differences between Shuar and Americans. First, learnability of animal danger was higher for the Shuar than the American children. As Barrett and Broesch (2012) point out, there are two possible reasons for this difference that our present data cannot disentangle. One possibility is that, given the greater risk that Shuar children face from animal danger, they are calibrated to remember animal danger information better than American children do, perhaps through increased attention to the information. Another possibility is an age effect: In the animal condition, the Shuar sample included a broader range of ages than the American sample, extending up to age 8, whereas the oldest American children were 5. An increase in learning ability with age is thus an alternate possible explanation for the population difference.

Another exception to the cross-cultural similarity in the learnability landscapes is the difference in learning about artifact danger, where American children show above-chance learning and Shuar children do not. There are several possible reasons for this difference. First, because the artifacts we selected were Western in nature—unfamiliar looking plastic and metal objects—they might have been more unfamiliar as a general category to the Shuar participants. Second, Shuar children in general are exposed to a lower diversity of artifacts than Western children are, so they might not be as accustomed to making fine-grained category distinctions between many types of artifact (German & Barrett, 2005). And finally, there may be a cultural difference in the degree to which children are wary of human-made artifacts, both because Shuar children, like children in many traditional societies, are allowed to handle potentially dangerous objects at much younger ages than typical Westerners, and because Western children may have more dangerous unfamiliar objects in their environments, such as electrical appliances and hazardous chemicals. Because we cannot adjudicate between these possibilities, they remain conjectures for future work.

We found no significant differences in recall between Test, immediately following training, and Retest 1 week later. This is consistent with Barrett and Broesch's (2012) original findings for animals, and suggests that the learning that is occurring here is long-term learning following a single trial without feedback. Rapid immediate learning may be typical for information learned via explicit instruction, where attention to the information is high—but it is interesting to note that performance after 1 week, during which much distraction presumably occurred, is not degraded.

The cultural transmission of information in our task involved teaching, because our intent was to measure learnability of information transmitted through explicit, propositionally based cultural transmission. However, this is not the only means by which information of the kinds we examined could be transmitted. Indeed, there remains controversy over just how much cultural transmission is done via teaching, as opposed to more passive modes of transmission such as observation of adult activities or conversation, in traditional societies (Kline, 2015; Lancy, 1996). Although we suspect that there might still be an effect of danger content on learning through passive (observational) cultural transmission, the exact shape of the learnability landscape would almost certainly differ between teaching and observational learning. This is an important question for future investigation.

Conclusion

Although there is much discussion and conjecture about the domain generality of processes of cultural transmission, there have been few attempts to quantify this domain generality by systematically manipulating dimensions of potential learnability while holding others constant. Although our efforts here are preliminary and specific to a particular region of learnability space, they are intended as a first step toward quantitative measurement of the learnability landscape. Of course, this is not the first study to measure cultural transmission; there exist many others, and the literature on experimental cultural transmission studies is rapidly growing (Mesoudi, 2011). However, to the extent that these studies use different measurement techniques and examine very different regions of the global learnability landscape, each is essentially point measurements in a very large space. A virtue of our method, as we see it, is the use of standardized learnability metric (binary items presented on flashcards), combined with systematic variation of information parameters to document how learnability changes as a function of those parameters. Although we recognize that this is just one of many possible methodologies, we hope that as this literature matures, efforts will be made to develop standard measurement tools that can be used to estimate effect sizes and to generate cumulative, mutually comparable databases on cultural transmission.

Again, although our initial efforts are modest, we see them as part of a general movement in the social sciences away from excessive reliance on null hypothesis significance testing (NHST) and toward measurement of effect sizes using robust and replicable methods (Cumming, 2014; Ioannidis, 2005). Although both approaches have their place in social science, debates framed around binary conceptual distinctions such as learning/innateness, biology/culture, and domain specificity/domain generality may persist in part because NHST is a tool that offers simple yes/no answers to questions. However, answers to many questions about development are likely to be more complex, involving interactions along multiple, continuous dimensions. For such questions, it can be useful to develop research designs that focus on measuring the size and nature of effects in ways that can be compared across studies, and to publish the resulting data in open format that can be accessed by multiple researchers. Although ours is by no means the only technique that can be used in this way, we hope that it inspires others to measure the ways in which multiple factors interact to shape learning and cultural transmission. We view the effort to map human learnability landscapes as part of a larger endeavor to quantify reaction norms of psychological development, which in turn can be seen as part of a growing movement to document, in detail, the human phenome.

In this spirit, we hope that quantitative cross-cultural measurement of development will help put an end to the idea that biology and culture are mutually exclusive explanations for human cognition and behavior. In the present study, for example, we think it is likely that there is at least some "biological" or evolved basis for the danger learning effects we observed. The plausibility of this proposal is enhanced by both the cross-cultural similarities in learning landscapes that we found and the fact that prepared social learning of danger is observed in other primates, suggesting the possibility of homologous, though possibly modified, learning mechanisms (Barrett & Broesch, 2012; Cook & Mineka, 1989). However, there is no reason why even this effect might not be influenced by cultural and ontogenetic factors, such as the relative risk of encounter with particular kinds of danger in the local environment. Indeed, one might expect adaptive plasticity in sensitivity to danger via evolved reaction norms: developmental mechanisms that adjust phenotypes, including the sensitivity of learning mechanisms, as a function of environmental circumstances (Frankenhuis & Panchanathan, 2011). Such adaptive plasticity may partly explain the increased danger learning effect for animals among the Shuar, and possibly the higher danger learning effect for man-made artifacts in the U.S. children. By manipulating factors relevant to evolutionary and cultural influences on learning within a single design, it is possible in principle to investigate how these influences interact to produce phenotypic outcomes. If done properly, this will help us to move past either–or debates about biology and culture—which nearly everyone agrees is not really an either–or question—and to begin measuring how biology and culture interact, synergistically, in building minds.

References

Baltazar, N. C., Shutts, K., & Kinzler, K. D. (2012). Children show heightened memory for threatening social actions. *Journal of Experimental Child Psychology*, *112*, 102–110. doi:10.1016/j.jecp.2011.11.003

Barrett, H. C. (2015). *The shape of thought: How mental adaptations evolve*. New York, NY: Oxford University Press.

Barrett, H. C., & Broesch, J. (2012). Prepared social learning about dangerous animals in children. *Evolution and Human Behavior*, *33*, 499–508. doi:10.1016/j.evolhumbehav.2012.01.003

Boyd, R., & Richerson, P. (1985). *Culture and the evolutionary process*. Chicago, IL: University of Chicago Press.

Carey, S. (2009). *The origin of concepts*. New York, NY: Oxford University Press.

Cashdan, E. (1994). A sensitive period for learning about food. *Human Nature*, *5*, 279–291. doi: 10.1007/bf02692155

Casler, K., & Kelemen, D. (2005). Young children's rapid learning about artifacts. *Developmental Science*, *8*, 472–480. DOI: 10.1111/j.1467-7687.2005.00438.x

Cook, S., & Mineka, S. (1989). Observational conditioning of fear to fear-relevant versus fear-irrelevant stimuli in rhesus monkeys. *Journal of Abnormal Psychology*, *98*, 448–459. doi: 10.1037/0021-843X.98.4.448

Cumming, G. (2014). The new statistics: Why and how. *Psychological Science*, *25*, 7–29. doi: 10.1177/0956797613504966

Curtis, V., Aunger, R., & Rabie, T. (2004). Evidence that disgust evolved to protect from risk of disease. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *271*(Suppl. 4), S131–S133. doi: 10.1098/rsbl.2003.0144

DiYanni, C., & Kelemen, D. (2008). Using a bad tool with good intention: Young children's imitation of adults' questionable choices. *Journal of Experimental Child Psychology*, *101*, 241–261. doi: 10.1016/j.jecp.2008.05.002

Feldman, M. W., Aoki, K., & Kumm, J. (1996). Individual versus social learning: Evolutionary analysis in a fluctuating environment. *Anthropology Science*, *104*, 209–231.

Fessler, D. M., Pisor, A. C., & Navarrete, C. D. (2014). Negatively-biased credulity and the cultural evolution of beliefs. *PLoS One*, *9*, e95167. doi: 10.1371/journal.pone.0095167

Fournier, D. A., Skaug, H. J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M., . . . Sibert, J. (2012). AD model builder: Using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software*, *27*, 233–249. doi: 10.1080/10556788.2011.597854

Frankenhuis, W. E., & Barrett, H. C. (2013). Design for learning: The case of chasing. In M. D. Rutherford & V. A. Kuhlmeier (Eds.), *Social perception: Detection and interpretation of animacy, agency, and intention* (pp. 171–195). Cambridge, MA: MIT Press.

Frankenhuis, W. E., & de Weerth, C. (2013). Does early-life exposure to stress shape or impair cognition? *Current Directions in Psychological Science*, *22*, 407–412. doi: 10.1177/0963721413484324

Frankenhuis, W. E., & Panchanathan, K. (2011). Balancing sampling and specialization: An adaptationist model of incremental development. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *278*, 3558–3565. 10.1098/rspb.2011.0055

Garcia, J., & Koelling, R. A. (1966). Relation of cue to consequence in avoidance learning. *Psychonomic Science*, *4*, 123–124. doi: 10.3758/bf03342209

Gelman, S. A., & Legare, C. H. (2011). Concepts and folk theories. *Annual Review of Anthropology*, *40*, 379–398.

German, T. P., & Barrett, H. C. (2005). Functional fixedness in a technologically sparse culture. *Psychological Science*, *10*, 1–5.

Henrich, J., & McElreath, R. (2003). The evolution of cultural evolution. *Evolutionary Anthropology*, *12*, 123–135.

Ioannidis, J. P. (2005). Why most published research findings are false. *PLoS Medicine*, *2*, e124.

Kemler Nelson, D. G., Russell, R., Duke, N., & Jones, K. (2000). Two-year-olds will name artifacts by their functions. *Child Development*, *71*, 1271–1288.

Klein, S. B., Cosmides, L., Tooby, J., & Chance, S. (2002). Decisions and the evolution of memory: Multiple systems, multiple functions. *Psychological Review*, *109*, 306–329.

Kline, M. A. (2015). How to learn about teaching: An evolutionary framework for the study of teaching behavior in humans and other animals. *Behavioral and Brain Sciences*, *38*, e31, 1–71. doi:10.1017/S0140525X14000090

Krasnow, M. M., Truxaw, D., Gaulin, S. J. C., New, J., Ozono, H., Uono, S., . . . Minamoto, K. (2011). Cognitive adaptations for gathering-related navigation in humans. *Evolution and Human Behavior*, *32*, 1–12. doi: 10.1016/j.evolhumbehav.2010.07.003

Laland, K. N., Odling-Smee, J., & Feldman, M. W. (2000). Niche construction, biological evolution, and cultural change. *Behavioral and Brain Sciences*, *23*, 131–146. doi: 10.1017/s0140525x00002417

Lancy, D. F. (1996). *Playing on the mother-ground: Cultural routines for children's development*. New York, NY: Guilford.

Lieberman, D., Tooby, J., & Cosmides, L. (2007). The architecture of human kin detection. *Nature*, *445*, 727–731. doi: 10.1038/nature05510

LoBue, V., & Rakison, D. H. (2013). What we fear most: A developmental advantage for threat-relevant stimuli. *Developmental Review*, *33*, 285–303. doi:10.1016/j.dr.2013.07.005

Mesoudi, A. (2011). *Cultural evolution: How Darwinian theory can explain human culture and synthesize the social sciences*. Chicago, IL: University of Chicago Press.

Mesoudi, A., Whiten, A., & Dunbar, R. (2006). A bias for social information in human cultural transmission. *British Journal of Psychology*, *97*, 405–423. doi: 10.1348/000712605x85871

Mineka, S., Davidson, M., Cook, M., & Keir, R. (1984). Observational conditioning of snake fear in rhesus monkey. *Journal of Abnormal Psychology*, *93*, 355–372. doi: 10.1037/0021-843x.93.4.355

New, J., Krasnow, M. M., Truxaw, D., & Gaulin, S. J. (2007). Spatial adaptations for plant foraging: Women excel and calories count. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *274*(1626), 2679–2684. doi: 10.1098/rspb.2007.0826

Öhman, A., Fredrikson, M., Hugdahl, K., & Rimmo, P. A. (1976). The premise of equipotentiality in human classical conditioning: Conditioned electrodermal responses to potentially phobic stimuli. *Journal of Experimental Psychology: General*, *105*, 313. doi: 10.1037/0096-3445.105.4.313

R Core Team (2014). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Rozin, P., & Fallon, A. E. (1987). A perspective on disgust. *Psychological Review*, *94*, 23–41

Rozin, P., & Royzman, E. B. (2001). Negativity bias, negativity dominance, and contagion. *Personality and Social Psychology Review*, *5*, 296–320. doi: 10.1207/s15327957pspr0504_2

Shutts, K., Kinzler, K. D., McKee, C. B., & Spelke, E. S. (2009). Social information guides infants' selection of foods. *Journal of Cognition and Development*, *10*, 1–17. doi: 10.1080/15248370902966636

Sperber, D., & Hirschfeld, L. A. (2004). The cognitive foundations of cultural stability and diversity. *Trends in Cognitive Sciences*, *8*, 40–46. doi: 10.1016/j.tics.2003.11.002

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 19–136). New York, NY: Oxford University Press.

Wertz, A. E., & Wynn, K. (2014a). Thyme to touch: Infants possess strategies that protect them from dangers posed by plants. *Cognition*, *130*, 44–49. doi: 10.1016/j.tics.2003.11.002

Wertz, A. E., & Wynn, K. (2014b). Selective social learning of plant edibility in 6 and 18-month-old infants. *Psychological Science*, *25*, 874–882. doi: 10.1177/0956797613516145

Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Data S1. Data File in .csv Format

Appendix S1. Sample Demographics

Table S1. Model Comparison Results

Table S2. Model With Domain and Property Modeled as Random Factors

Table S3. Mean Performance by Condition, With Upper and Lower Bounds on Confidence Interval (CI, ± 95%)