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Original Article

Prestige-biased cultural learning: bystander's differential attention to potential models influences children's learning☆

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Abstract

Reasoning about the evolution of our species' capacity for cumulative cultural learning has led culture–gene coevolutionary (CGC) theorists to predict that humans should possess several learning biases which robustly enhance the fitness of cultural learners. Meanwhile, developmental psychologists have begun using experimental procedures to probe the learning biases that young children actually possess — a methodology ripe for testing CGC. Here we report the first direct tests in children of CGC's prediction of *prestige bias*, a tendency to learn from individuals to whom others have preferentially attended, learned or deferred. Our first study showed that the odds of 3- and 4-year-old children learning from an adult model to whom bystanders had previously preferentially attended for 10 seconds (the *prestigious* model) were over twice those of their learning from a model whom bystanders ignored. Moreover, this effect appears domain-sensitive: in Study 2 when bystanders preferentially observed a prestigious model using artifacts, she was learned from more often on subsequent artifact-use tasks (odds almost five times greater) but not on food-preference tasks, while the reverse was true of a model who received preferential bystander attention while expressing food preferences.

Keywords: Prestige bias; Selective imitation; Children; Learning

Human cognition is distinct in the degree to which it is shaped by *cultural learning* (i.e., information learned from others), in addition to individual experience and genetics. The cognitive mechanisms that shape and bias the acquisition of cultural information (which includes emotional responses, food preferences, cognitive and behavioral heuristics, etc.) have broad relevance to understanding human cognition and behavior. A key step in establishing the generality of such biases is probing their developmental trajectory. Evolutionary theorists have made a priori predictions about such biases (i.e., predictions entailed by evolutionary theory rather than explanations fitted to existing empirical evidence), but so far we know of no direct tests in children of these predictions. Below we review plausible candidates for evolved cultural learning biases and present direct tests of one — prestige bias — in 3- and 4-year-old participants.

Several important lines of theoretical work have sketched cognitive foundations for our species' capacity for cumulative cultural learning. These accounts variously emphasize, for instance, intention reading and attention sharing (Tomasello, Carpenter & Behne, 2005), ostensive pedagogy (Csibra & Gergely, 2009; Gergely & Csibra, 2005), cognitive fluidity (Mithen, 1996) and mental time travel (Boyer, 2008). Among these, culture–gene coevolutionary (CGC) theories focus on and model the evolutionary dynamics facing an emerging cultural species, in particular the interaction of genetic and cultural inheritance systems (Boyd & Richerson, 1985) and the learning biases these interactions select for (Cavalli-Sforza & Feldman, 1981; Eriksson, Enquist & Ghirlanda, 2007; Kendal, Giraldeau & Laland, 2009; Mesoudi, 2009; Richerson & Boyd, 2005).

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By bringing together empirical evidence of human ancestral history and evolutionary models focused on understanding our capacities for cultural learning, CGC theories have derived predictions supported by a wide range of evidence from social psychology, economics, field studies and paleoarcheology (Galef & Whiskin, 2008a; Laland, 2004; Mesoudi, 2009; Powell, Shennan & Thomas, 2009; Richerson & Boyd, 2005; for a review, see Henrich & Henrich, 2007; Richerson & Boyd, 2005: chapter 2). CGC approaches suggest, among others things, that learners should be selective about who they attend to for the purpose of cultural learning. They specify a suite of hypotheses about which cultural learning strategies most effectively extract useful, adaptive information.

Strategies concerning *from whom to learn* are termed “model biases.” Some individuals are just better in certain domains, or possess more relevant information, and it pays to learn from them. Alongside cues based on age, sex, health and dialect (cuing ethnicity), CGC specifies three candidates for evolved model biases: skill bias, success bias and prestige bias. “Skill bias” entails learners selecting models by direct perception of their competence, which can be inaccurate (i.e., when it is not obvious to naïve learners how to judge competence) and costly (i.e., when careful observation of many individuals is needed to gauge skill differentials). “Success bias” entails learners selecting models by the accumulated symbols of their success, which can vary between societies; for instance, greater wealth, fancier ornamentation (Malinowski, 1922) or bigger yams (Kaberry, 1941). “Prestige bias” entails learners preferring information from models to whom other learners have preferentially attended or deferred (Henrich & Gil-White, 2001). Prestige bias facilitates more accurate and rapid learning by capitalizing on others’ knowledge about who is worthy of attention. Because others’ preference for better-quality models is, for a cultural species, fairly reliable across generations and cultures, prestige bias, as an adaptation for exploiting this regularity, is a good candidate for a genetically evolved, cultural learning bias.

We direct readers to Henrich and Gil-White (2001) for a complete description of prestige bias, but include here a caution aimed at a common misunderstanding. Prestige bias, a technical coinage, does not denote *prestige*’s usual English meaning (an acknowledged status difference); rather, it refers to learners’ preference for inferring cultural information from whomever receives more attention and/or freely conferred deference from other learners.[1] This difference results when learners prefer to attend to and hang around their more skillful peers, avoid attending to less skillful ones or, more likely, both. CGC’s key prediction is that cues of differential attention and/or deference, alongside other sources of information about model quality, will be exploited by members of a cultural species because they reliably discriminate better from worse models across societies and epochs.

Among adults, evidence for CGC’s predicted biases (see Henrich & Henrich, 2007, for a review) has emerged from social psychology (Henrich & Gil-White, 2001), behavioral economics (Pingle & Day, 1996), experimental anthropology (Efferson, Lalive, Richerson, McElreath & Lubell, 2008), field studies (Rogers, 1995) and even corollaries in non-human animals (Galef & Whiskin, 2008a; Galef & Whiskin, 2008b; Horner, Proctor, Bonnie, Whiten & de Waal, 2010).

Recent investigations into children’s strategies for extracting information from their social environment (for a recent review see Gelman, 2009) also provide support for CGC predictions. Predictions of an innate or rapidly acquired skill bias are supported by young children’s tracking and preferential learning from more accurate models (e.g., Birch, Vauthier & Bloom, 2008; Brosseau-Liard & Birch, in press; Clement, Koenig & Harris, 2004; Corriveau & Harris, 2009; Koenig & Harris, 2005), more confident models (Birch, Akmal & Frampton, 2010; Jaswal & Malone, 2007; Rakoczy, Warneken, & Tomasello, 2009; Sabbagh & Baldwin, 2001), artifact makers about their artifacts (Jaswal, 2006) and, generally, adults over children, but accurate children over inaccurate adults (Jaswal & Neely, 2006). Similarly, predictions about models’ dialect as a cue in cultural learning (Boyd & Richerson, 1987; McElreath, Boyd & Richerson, 2003) are supported by developmental investigations of selective learning (Kinzler, Dupoux & Spelke, 2007; Shutts, Kinzler, McKee & Spelke, 2009). While these findings fit CGC predictions prima facie, the studies were typically designed to glean proximate insights rather than test evolutionary predictions about biased cultural learning. They are, however, quite consistent with a large body of earlier theoretical work (e.g., Boyd & Richerson, 2005).

The present studies directly test for prestige-biased cultural learning in 3- and 4-year-olds. To date, the developmental evidence most relevant to prestige bias comes from Fusaro and Harris (2008). Their 4-year-old participants saw two models labeling the same object differently while bystanders non-verbally either endorsed (nodding and smiling) or denied (shaking their heads) the models’ statements. Children preferentially learned from the affectively endorsed model — even on subsequent tests without bystanders present. Yet this design was not intended to and consequently did not directly test prestige bias for two reasons. First, bystanders gave models differential assent (via their affective displays), rather than purely different amounts of attention. This assent potentially endorsed the model *and* their message, making it impossible (for the purpose of testing adaptive theories of cultural learning) to distinguish prestige bias from skill bias

[1] In our experiments, the “prestigious model” is distinct only by receiving bystanders’ preferential gaze.

or conformist bias[2] — a distinct learning mechanism (Eriksson et al., 2007; Henrich & Boyd, 1998; Kendal et al., 2009) which may be amenable to different developmental investigations (for instance, some insight can be drawn from Corriveau & Harris, 2010; Corriveau, Fusaro & Harris, 2009) . Second, children only learned novel labels; thus the observed effects may apply only to language learning, rather than constituting the broader learning bias predicted by CGC. Language acquisition may be a special domain of learning (e.g., Pinker, 1994), particularly because it concerns coordinating with one's group rather than adapting to the non-social environment. For example, while some fungi really are better (and safer) to eat than others (and people can learn this culturally), whether one should call them *mushrooms* or 茸 depends only on what others call them. Furthermore, linguistic disagreements between models may be a cue to ethnic differences, which have also been formally predicted (McElreath et al., 2003) and shown (Kinzler et al., 2007; Shutts et al., 2009) to bias children's behavior.

1. Predictions

We set out to test the hypotheses that young learners are

(1) *prestige-biased*: they will preferentially learn from models to whom bystanders pay more visual attention (gaze) even without explicit endorsement, and
(2) *prestige-biased in various domains, including potentially costly behavioral domains*: they will learn preferences and behaviors, not just language, including those in potentially costly domains like food and drink choices.

2. Study 1

2.1. Method

2.1.1. Participants

We measured the selective learning of 23 children (mean age=50.4 months, S.D.=5.8 months; 12 girls) recruited from a participant database at a public university. Data from one boy who did not complete the experiment were excluded. The majority of participants were Caucasian or Asian; all were from households where English was the main language spoken.

[2] Note: this is again a technical term, referring to a non-linear relationship between the frequency of a cultural trait and the probability of its being learned. Readers should be careful not to confuse this with other uses of the word *conformity*, which can involve concerns about coordination, signaling, explicit norms and social punishment. Conformist bias is also indirectly supported (i.e., these studies were not designed to test this evolutionary prediction, but their results support it) by developmental evidence (Corriveau & Harris, 2009).

2.1.2. Procedure

Participants watched an "attentional cuing" clip, where two models received unequal bystander attention. In this cuing scene two bystanders stood between the models, attending to only one of them — the "prestigious model." This prestige cuing was followed by four 10-seconds (s) "test" clips, where those two models demonstrated different behaviors, preferences and labels. In all test clips solitary models demonstrated their preference towards an object; then participants' own preferences toward those same stimuli were recorded. The order in which models appeared and the identity of the prestigious model were counter-balanced across participants. Participants observed the scenes in the following order (see Fig. 1).

Food Choice: Models made a disgusted face at either large round or small square crackers and happily sampled the other. Participants saw this scene before the cuing scene but only later, during "free play," were they offered a choice between the two crackers; they were asked: "Would you like a snack? Which of these would you like?" This element of our design let us probe whether children apply prestige information retrospectively.

Attentional Cue: Each model played with a toy in different ways, on opposite sides of a room. Two observers entered and for 10 s stood between and slightly behind the models, angled toward and watching the prestigious model.

Artifact Use: Models interacted with a novel toy by delightedly using either colored balls or blocks. Participants were presented with the same apparatus, offered a choice of the balls or blocks and asked: "Can you show me how to play with this?"

Beverage Choice: Models made a disgusted face at either a cup of dyed blue or yellow water and drank from the other. Participants were offered the same two choices and asked, "Would you like a drink?" or if unwilling to drink: "Which do you think is better to drink?"

Novel Label Preference: Each model labeled a different object with the same name — a "stroop." Participants were presented with both objects and asked "Can you give me the stroop?"

Explicit Questions: After a few minutes of "free play," participants were shown photos of the models and asked: "Who would you rather play with" and "Who do you think is more popular, who has more friends?"

3. Results and discussion

Since participants always made binary choices, with each choice representing an implicit endorsement of one model as preferred, we analyzed our data using logistic regression. Since each participant made multiple, related binary choices, we compensated for the non-independence of these repeated observations by calculating clustered robust standard errors (clustering on individuals), using standard techniques (White, 1980). To compare different logistic regressions,

Fig. 1. Scenes that children saw in Study 1 in the order they saw them.

we conducted log-likelihood ratio tests;[3] the significance of coefficients was judged by their Z-distributed ratio to their standard errors. For each analysis, we started from a regression containing all the predictors (reported in Table 1), then removed non-significant predictors only if doing so did not significantly diminish the predictive power of the regression (these parsimonious models are reported in Table 2).

We conducted two kinds of regressions. First we regressed which model children learned from onto whether that model was the "prestigious model" (i.e., the person that child had seen bystanders preferentially watching) and our covariates (age, sex and the order in which models appeared). The resulting coefficient of the "prestige" predictor estimates the effect size of prestige bias (how many times greater a model's odds of being learned from are, if she's the prestigious model; reported as the odds ratio, OR), controlling for the covariates' effect on participants' model choice. Next we regressed whether the prestigious model was learned from onto the covariates, to analyze their effect on participants' proclivity to prestige bias.

3.1. Is children's learning prestige-biased?

Yes. Our analysis regressed which model participants learned from on (1) models' "prestige" (i.e., which model received bystander attention), (2) the order in which models appeared, (3) participants' sex and (4) participants' age. As shown in Table 1 under the "Pooled" regression, this produced only one significant predictor: prestige (p=.01). Removal of the non-significant predictors did not significantly diminish the regression's predictive power ($P[\chi^2(3)>2.1]$=.55), as shown in Table 2. In this parsimonious single-predictor regression (p_{LLRT}=.03), the odds of a cultural model being learned from were 2.37 times ($\mathrm{CI}_{.95}$=[1.22–4.58], p=.01) greater if she was the prestigious model. Regressing covariates on whether the prestigious model was learned from showed that participants' proclivity to prestige-bias was not confounded by their age (p=.32), sex (p=.70), the order in which models appeared (p=.11), nor which actor was the prestigious model (p=.48). Since prestige (i.e., bystander attention) significantly predicted learning across all measures pooled together, we also examined theoretically interesting subsets.

3.2. Is learning prestige-biased across domains?

Participants witnessed models receiving unequal attention from two bystanders while demonstrating different techniques for using an artifact; however, our non-explicit tests fell into three domains: (1) artifact use (involving a different artifact from the cuing scene); (2) food and drink preferences (i.e., the food and drink measures taken together as indexing a single construct); and (3) linguistic labels for novel objects. In both behavioral domains (i.e., artifact and food/drink), children were significantly more likely to learn from the prestigious model; the odds of them doing so were 8.25 ($\mathrm{CI}_{.95}$=[1.15–59.00]) times greater for artifact use and 4.09 ($\mathrm{CI}_{.95}$=[1.02–16.38]) times greater for food and drink preferences pooled together. When analyzed independently, neither food (OR=6.91, p=.10) nor drink (OR=2.59, p=.32) reached significance alone. Since both measures trended quite strongly towards prestige-bias, this was plausibly a consequence of our limited statistical power, which we address with a larger sample in our second study. Prestige-bias did not extend to language learning, the only measure which trended away from prestige bias (OR=.57, p=.60).

Table 1
Full models — Logistic regression coefficients (standard errors)

Predictors	Statistical models			
	Pooled	Artefact	Food and drink	Labelling
Prestige	.90 (.37)[c]	2.60 (1.30)[b]	1.42 (.67)[b]	−.57 (1.07)
Sex	.00 (.34)	−1.33 (1.43)	1.30 (.73)[a]	−2.90 (1.48)[b]
Order	−.56 (.33)[a]	−2.49 (1.50)[a]	−.42 (.57)	−1.94 (1.36)
Age	−.02 (.03)	−.08 (.14)	.03 (.06)	.01 (.10)
p_{LLRT}	.16	.04	.14	.13
n	100	23	44	23

Logistic regression coefficients and their standard errors. All statistical models regress which actor participants imitated onto the listed predictors. Prestige encodes which actor was prestigious, Sex is the sex of the participant, Order encodes which actor appeared first and Age is the participant's age in months. p_{LLRT} is the result of a log-likelihood ratio test of the model's goodness of fit. n is the number of observations on which the statistical inference was based, whose non-independence was compensated for by Huber–White clustered robust standard errors.

[a] p<.1.
[b] p<.05.
[c] p<.01.

[3] That is, we compared the χ^2 distributed ratio of each regression model's log likelihood to one another (reported as χ^2 tests) or to that of a logistic regression model with only a constant predictor (reported as p_{LLRT}). Values indicate the probability that the improvement in model fit would arise by random sampling alone. We refer to statistical models as "regressions" in the text to avoid confusion with the term "model" used to refer to the adults in our videos: the "cultural models".

Table 2
Parsimonious models — Logistic regression coefficients (standard errors)

Predictors	Statistical models			
	Pooled	Artefact	Food and drink	Labelling
Prestige	.86 (.33)[c]	2.11 (1.0)[b]	1.4 (.7)[b]	
Sex			1.5 (.7)[b]	−1.84 (.98)[a]
p_{LLRT}	.03	.02	.04	.04
n	100	23	44	23

Significant logistic regression coefficients and their standard errors. All statistical models regress which actor participants imitated onto the listed predictors. Parsimonious models were developed by removing only those non-significant predictors from the full models whose absence did not significantly diminish the model's log-likelihood. Prestige encodes which actor was prestigious, and Sex is the sex of the participant. p_{LLRT} is the result of a log-likelihood ratio test of the model's goodness of fit. n is the number of observations on which the statistical inference was based, whose non-independence was compensated for by Huber–White clustered robust standard errors.

[a] $p<.06$.
[b] $p<.05$.
[c] $p<.01$.

3.3. Did prestige bias children's explicit answers?

Children's answers to our explicit questions about which model they or others would prefer to play with were statistically indistinguishable from chance (p_{LLRT}=.80).

3.4. Does prestige-bias operate retrospectively?

Our participants observed models' food preferences *before* the prestige cue, but had their own food preference tested *after*. That this measure trended towards prestige-bias without reaching statistical significance, though peripheral to our main findings, may be of interest to researchers investigating similar phenomena.

4. Discussion: study 1

Our first study constitutes the first clear experimental evidence of prestige-biased learning in children, a disposition to learn from those to whom others preferentially attend. On novel tasks in the absence of any bystanders, the odds of our participants learning from a model to whom bystanders had previously preferentially attended were more than twice the odds of their learning from the other model. More precisely, children more often learned from an adult model who had received 10 s of bystanders' attention (gaze) than one who had not.

While demonstrating the basic effect, this preliminary study also raised some pressing questions. Our artifact-use test registered a much stronger effect than our food-preference tests, and our language-learning test registered no effect at all, despite the prior experimental evidence that children do discriminate their language-learning models (e.g., Fusaro & Harris, 2008; Jaswal & Neely, 2006). Since the order of our tests was fixed, this may have been the result of participant fatigue. It is also plausible that children's prestige bias is domain-sensitive: children are more likely to learn from prestigious models in domains more similar to those in which they received the preferential attention of bystanders. For instance, witnessing bystanders preferentially observing a model using a tool could make children more disposed to learn her other tool-use techniques, but not her food preferences or other habits unrelated to tool use.

Study 2 was designed to control for experimental fatigue and other order effects and to address the question of domain sensitivity by manipulating the domain in which prestige was cued.

5. Study 2

5.1. Method

5.1.1. Participants

Forty-eight children (mean age=46.6 months, S.D.=7.4 months; 25 girls) participated; all were recruited from a participant database. The majority of participants were ethnically North American or Asian; all were from households where English was the main language spoken.

5.1.2. Procedure

In Study 2, we systematically counterbalanced the domain in which prestige (specifically, differential bystander attention) was established between artifact-use and food-and-drink preferences (herein food preferences). After cuing a model's prestige in one of the two domains, we presented participants with learning tests in both domains (order counterbalanced). There were two test trials for each domain for a total of four test trials. The first two test trials were designed to minimize the feedback participants received on whether they had made a good choice to avoid any potential impact this could have on subsequent test trials. To demonstrate that *prestige* biases decisions which children expect will have real consequences, rather than just their answers to arbitrary questions, later test trials involved tangible rewards (i.e., a snack to eat and a sticker from the novel machine).

Subjects were assigned to one of two conditions; each contained, in order, two "initial cuing scenes" (either artifact use or food preference) in a fixed order; two "no feedback tests"; one "reminder cue" in the same domain as the initial cues; two "tangible consequence tests"; and, finally, two explicit questions.

During *prestige* cuing scenes, participants saw videos of two female models either interacting with artifacts or demonstrating food preferences, while three female bystanders attended to just one of these models (the "prestigious model"). During tests, participants saw videos of these models alone, demonstrating artifact-use techniques or food preferences by making a choice between two options. The following are detailed descriptions of these components, in order of appearance.

5.1.2.1. Initial cueing scenes. In each condition, participants saw two cues from a single domain (artifact or food) presented in the following order.

Artifact, Drawing: Bystanders watched one of the two models drawing with colored crayons on paper. The drawings were indistinguishable on the video.

Artifact, Building: Bystanders watched one of the two models connecting together small magnetized balls and sticks.

Food, Eating: Bystanders watched models eat similar looking crackers, one model selected food from a round white plate in front of her, the other from a square one.

Food, Drinking: Bystanders watched models pouring water into plastic cups from two very similar water coolers and then taking a drink.

5.1.2.2. No feedback tests. Next, all participants were presented with the following two tests. They saw each model one at a time and then made a forced choice between what they had seen demonstrated. The order in which they saw the tests and the order in which models appeared were counterbalanced between participants.

Artifact, Geo-Board Test: Models sat behind a "geo-board", a small wooden board with a lattice of small nails protruding from it; to their left and right were paper plates, one bearing green plastic blocks and the other green loops. Each model shook their head at one of these plates and then happily placed the contents of the other onto the geo-board. Participants were presented with the same geo-board, blocks and loops and asked, "Can you show me how to use this?" If they had not volunteered an answer within 10 s, they were prompted, "Which of these do you think you should use?" Participants did not receive feedback on whether they had made the right choice to avoid biasing later tests.

Food, Drink Test: Models sat between a white and a black can of otherwise identical canned beverages. Each made a disgusted face at one and then took a drink from the other. Participants were asked, "Which of these do you think is yummier?" Again, participants were not given any feedback on their choice or allowed to sample the drink.

5.1.2.3. Reminder Cue. Next, participants saw an additional prestige cue in the same domain as their initial cues. The same model was cued as prestigious.

Artifact, Toys: Bystanders watched models play with identical toys in different ways.

Food, Disgust: Bystanders watched models make a disgusted face towards two identical-looking plates of crackers. Models then crossed the room (still visually tracked by bystanders) and took a cracker from the plate the other model had disliked.

5.1.2.4. Tangible consequence tests. Next, all participants were presented with two tangible consequence tests. Again they saw models one at a time before making a binary forced choice. Test and model order were counterbalanced.

Artifact, Sticker-Machine Test: Models sat behind a "sticker machine," a grey box with two visually salient orange handles protruding from it. Each model shook their head at one handle and then very deliberately reached for the other. To ensure participants did not have information about the success of each technique, clips terminated just before models actually manipulated the machine. Children were told, "You can get a sticker from this machine if you use it right. Do you want to try using it? Can you show me how?" When children manipulated either handle, a door opened in the sticker machine and children were given the sticker inside. A small proportion of shy children merely pointed to one handle and the experimenter manipulated it for them.

Food, Container Test: Models sat between two white containers, one square and one round. Each model opened one container towards herself (so participants could not see the contents) and made a disgusted face and then similarly checked the other container but happily reached inside. Children were presented with both containers and told "I have two snacks here. You can have a snack, but you can only choose *one.* Which one would you like?" In either container children found a fruit-flavored gummy candy, which they were allowed to eat.

5.1.2.5. Explicit questions. Children were asked "Who would you like to play with?" and then "Who were the girls looking at?" and answered by pointing to pictures of the models. If subjects hesitated with the second question, they were further prompted: "The girls standing in the middle, did they look at this girl or this one?"

6. Results and discussion

Our analysis here parallels Study 1. Again, regressing which model was learned from on which model was prestigious (see Table 3) yielded our effect size estimate for prestige bias, expressed as an odds ratio (OR) estimated by the *prestige* predictor. Here, we put greater emphasis on regressing whether the prestige model was learned from on our predictors (see Table 4), allowing us to estimate how each predictor (particularly the domain of the tests and cues) changed the strength of prestige bias. In this second set of regressions, the absolute effect size of prestige bias is instead estimated by the intercept; in Table 4 we have mean centered our variables to make this interpretation straightforward.

6.1. Was children's learning prestige-biased?

Yes. Regressing which model was learned from on prestige, age, sex, order in which prestigious model appeared, test domain and cue domain produced only one significant predictor of model preference, prestige (OR=2.11, $CI_{.95}$=[1.06–4.22]) (see Table 3: Basic). Removing non-significant covariates reduced the predictive power of the regression, but did not substantially change the effect

Table 3
Study 2 — Prestige models

Predictors	Statistical models			
	Basic	Parsimonious basic	Interaction	Parsimonious interaction
Prestige	0.75 (0.35)[a]	0.74 (0.31)[b]	1.56 (0.47)[b]	1.64 (0.43)[b]
Sex is male	0.32 (0.33)		0.33 (0.35)	
Age	0.00 (0.01)		0.00 (0.01)	
Order	0.35 (0.34)		0.37 (0.35)	
Cue is food	0.25 (0.32)		0.27 (0.33)	
Test is food	0.11 (0.26)		0.12 (0.24)	
Cross-domain			1.01 (0.37)[b]	1.01 (0.37)[b]
Cross-domain∗prestige			−1.54 (0.49)[b]	−1.51 (0.48)[b]
p_{LLRT}	.04	.01	.002	.001

Logistic regression coefficients and their standard errors. All statistical models regress which actor participants imitated onto the listed predictors. Prestige encodes which actor was prestigious, Sex is Male encodes participants' sex, Order encodes which actor appeared first and Age is the participant's age in months. Cue is Food and Test is Food encode which domain the cue and test were in, respectively. Cross-Domain is true when the test and cue are in different domains and false otherwise. p_{LLRT} is the result of a log-likelihood ratio test of the regression's goodness of fit. All regressions were based on 191 observations whose non-independence was explicitly modelled by computing Huber–White clustered robust standard errors.
Prestige significantly biases learning across all tests (i.e., prestige, basic regressions). This is particularly true in the same domain as the model's prestige cue (i.e., prestige, interaction regressions), while the effect is almost zero in the other domain (i.e., Prestige − Cross-Domain∗Prestige, interaction regressions). Exponentiating the prestige coefficient yields our effect size measure: the ratio of the odds of imitating the prestigious model to the odds of imitating the other model.

[a] $p<.05$.

[b] $p<.01$.

of the prestige predictor (see Table 3: Parsimonious Basic). Regressing whether the prestigious model was learned from on these covariates did not produce any significant predictors of participants' proclivity for prestige biased learning (see Table 4: Basic).

6.2. Was prestige bias stronger in the domain where prestige was cued?

Yes, in fact it was absent in the other domain. There are two ways to analyze this effect, each using a variable which encodes whether the test was in the same domain (artifact or food) as attentional cues. First this variable can predict which model children learned from as a multiplicative interaction with model prestige. This approach (summarized in Table 3: Interaction and Parsimonious Interaction) produced a significant interaction (b=1.54, S.E.=0.49, $p<.01$) and effect-size estimate in terms of the models: being prestigious improved a model's odds of being learned from by 4.75 ($\text{CI}_{.95}$=[1.91–11.8]) times on same domain tests, but not (p=.96) on cross-domain tests.

A conceptually simpler approach for examining this is to add "cross-domain" as a predictor of whether children learned from the prestigious model. This model (summarized in Table 4: Domain Model) produced only one significant predictor and effect estimate in terms of proclivity to prestige bias: when tests were in the same domain as cues, the odds of children learning from the prestigious model were 2.09 ($\text{CI}_{.95}$=[1.30–3.36]) times greater. This effect shifted the probability of learning from the prestigious model from about 52% (p=.72) on cross-domain tests to about 69% ($p<.001$) on same-domain tests. These effects are illustrated visually in Fig. 2, where it is apparent that though food tests trended non-significantly towards prestige bias when children saw artifact cues, artifact tests showed the opposite trend when children saw food cues. Each individual test showed the same domain-sensitivity effect (see Fig. 3),

Table 4
Study 2 — Covariate models

Predictors	Statistical models		
	Basic	Domain	Parsimonious domain
Intercept	0.42 (0.16)[a]	0.81 (0.21)[a]	0.79 (0.21)[a]
Model	0.43 (0.36)	0.45 (0.37)	
Sex	0.01 (0.34)	0.01 (0.35)	
Age	0.00 (0.01)	0.00 (0.01)	
Order	0.27 (0.34)	0.27 (0.35)	
Cue	−0.22 (0.32)	−0.23 (0.33)	
Test	0.02 (0.26)	−0.03 (0.25)	
Cross-domain		−0.74 (0.24)[a]	−0.73 (0.24)[a]
p_{LLRT}	.7	.07	.002

Logistic regression coefficients and their standard errors. All statistical models regress whether participants imitated the prestigious model onto the listed predictors. Model encodes which particular actor was prestigious, Sex indicates whether the participant was male, Order encodes which actor appeared first and Age is the participant's age in months. Cue and Test encode which domain the cue and test were in, respectively. Cross-Domain is true when the test and cue are in different domains and false otherwise. p_{LLRT} is the result of a log-likelihood ratio test of the model's goodness of fit. All tests were based on 191 observations whose non-independence was explicitly modelled by computing Huber–White clustered robust standard errors.
For ease of interpretation, all variables are mean-centered, besides Cross-Domain. This allows the logistic intercept {+ the Cross-Domain coefficient}, to be directly transformed $\left\{\frac{1}{1+e^{-\beta_0}}\right\}$ to the proportion of participants who imitated the prestigious model on tests in the same {or cross} domain.

[a] $p<.01$.

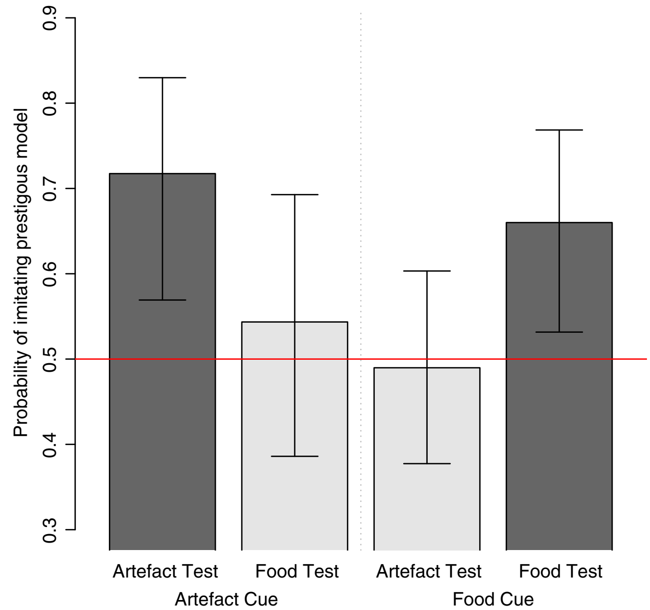

Fig. 2. Probability of children imitating the prestigious model with 95% confidence intervals, in the same domain as the prestige cue (darker bars) and the other domain (lighter bars).

though when analyzed independently this difference only reached conventional levels of significance for the geo-board test (p=.04).

6.3. Did prestige bias children's explicit playmate preferences?

No. Regressing who children chose as their playmate on the full set of predictors produced no significant effects, including prestige (p=.45).

6.4. Did children explicitly recall who bystanders had attended to?

No. Only 22 (46%) of our participants indicated who bystanders had looked at, the remainder either said they did not know or "both". Of those, only 12 (54%) correctly identified the prestigious model. Who children explicitly identified as having been attended to neither significantly predicted who they learned from (p=.55), nor was it predicted by who had been cued as prestigious (p=.64).

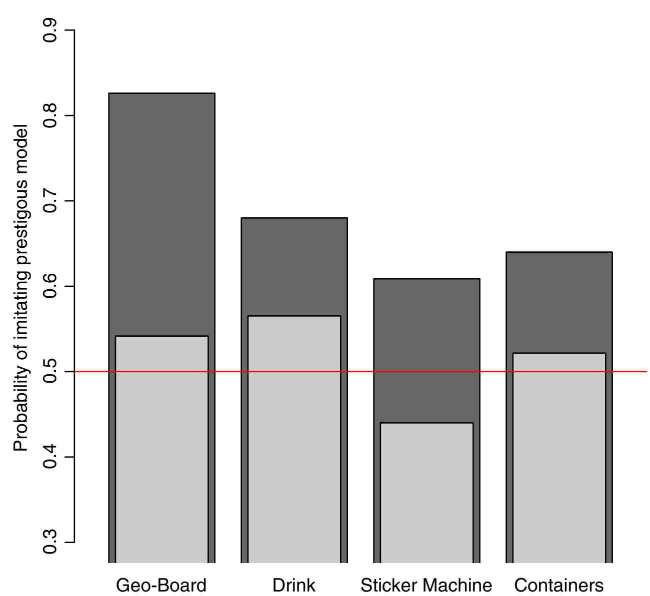

Fig. 3. Probability of children imitating the prestigious model on each test, when they had seen a cue in the cross domain (lighter bars) or the same domain (darker bars). The only test for which this difference was significant when analyzed alone was the geo-board (p=.04).

7. Discussion: study 2

Study 2 constitutes the first evidence that children's prestige-biased learning is intelligently targeted at domains in which models were observed receiving differential attention. This effect was consistent across multiple instances of learning in the same domain, for choices both with and without immediate tangible consequences. Particularly interesting is the fact that our participants were not able to reliably, explicitly recall which model had received bystander attention, nor were their explicit preferences for which model they had liked as a playmate influenced by our cuing of prestige. We tested the domain sensitivity of prestige bias using two instances of two learning domains likely to be of particular importance in an evolutionary context: artifact use and dietary preferences. This work opens the door to more systematic inquiries using multiple exemplars from many different learning domains.

8. General discussion

Our findings provide support for the existence of a domain-sensitive prestige bias in children's learning: children's learning from cultural models was biased by the mere preferential attention of bystanders, particularly on activities similar to those the model had been engaging in when she received bystander attention. These strong effects from a minimal manipulation suggest that prestige bias may be a potent pressure on cultural evolution. As predicted (Henrich & Gil-White, 2001), we witnessed biased learning in different domains, including potentially costly dietary preferences.

Our tests bear out a behavioral phenotype predicted a priori by CGC theorists, i.e., on the basis of evolutionary reasoning undertaken prior to this phenotype being observed. Importantly, CGC predicts the behavioral consequences of prestige bias but remains agnostic to the cognitive mechanisms that implement it. The domain sensitivity we observed in our second study speaks against the possibility of prestige bias resulting from general attentional biases. For instance, if children's disposition to follow the gaze of bystanders (Flom, Lee & Muir, 2007) were simply creating a more salient representation of the prestigious model in memory, one would expect that representation to precipitate a bias to learn from that model regardless of the learning domain. Although the mechanisms driving prestige bias remain largely opaque, our results suggest that they encode and selectively exploit at least two pieces of information: the relative amounts of third-party attention that potential models receive and the domain of activity in which they receive it. The fact that children do not seem to explicitly recall the former when asked suggests that these mechanisms operate outside conscious awareness or direct introspective access.

The potency of this combination of prestige bias and domain specificity did not increase with the age of our subjects, suggesting that it may be in place or fully developed prior to 3 years of age. CGC's prediction is consistent with either an innate[4] prestige bias or innate, evolved cognitive mechanisms which make acquiring prestige bias by individual learning substantially more likely. Our results are consistent with either of these possibilities, although future work could help tease them apart. Although our study is cross-sectional, it does span a key developmental window when most children begin passing classic (explicit) false-belief tests, a variable correlated with many other cognitive changes (Wellman, Cross & Watson, 2001) including social learning preferences (e.g., Fusaro & Harris, 2008). To the extent that our participants' age serves as a proxy for these cognitive developments, they seem to neither potentiate nor strengthen prestige bias. However, further work which explicitly measures understanding of false beliefs and tests prestige bias at other developmental stages will greatly clarify this picture.

With regard to cross-domain effects, Henrich and Gil-White (2001) predicted that prestigious individuals are "influential, even beyond their domain of expertise." Recent developmental research (Fawcett & Markson 2010) has indicated that 2-year-olds who know a model shares their preferences in one domain (food or television shows) will only imitate that model's preferences in that same domain, not the other. This suggests that mere "similarity cues" may not be strongly influential beyond their domain of expertise. In our work with "prestige cues", we witnessed an interesting domain-based asymmetry. Our subjects' food and drink preferences trended toward prestige-bias when they saw artifact-use cues (in study 1, the combined food and drink measures registered a significant effect after a prestige cue, but each measure independently did not); however, their artifact-use preferences trended away from prestige-bias after seeing food cues. This raises the interesting possibility that children's inferences about model quality exploit an asymmetric map of the relationships between learning domains. While future work could document these relations, at present we merely speculate that children might form cognitive representations of the correlations between skill domains. Such correlations do exist out in the world, because

(a) skill at certain tasks (e.g., foraging and dietary choices, but not weight-lifting) relies on the same underlying traits (i.e., local ecological knowledge),
(b) skills at certain tasks (e.g., hunting) is influenced by performance in others (e.g., healthy dietary choices), while the reverse may not be true, and
(c) competence at hard tasks implies competence at easier ones but not necessarily harder ones (and inversely, incompetence at easy tasks implies incompetence at harder ones).

[4] The concept of innateness is defined differently by different groups and easily misunderstood (Samuels, 2004). We mean: it reliably develops, insensitive to environmental variations that humans usually encounter.

If such correlations were sufficiently regular throughout our evolutionary history, selection may have shaped cognitive mechanisms that more readily recognize them, generating regular patterns of asymmetric, domain-sensitive biased learning in children. Although developmental psychologists have given considerable attention to identifying innate domains in children's learning and reasoning (e.g., Spelke & Kinzler, 2007), many questions still remain about how children represent the relationships between different domains, including their relative difficulty (e.g., Keil, Lockhart & Schlegel, 2010). Since evolutionary speculation is notoriously error prone, confidently predicting evolved domain sensitivity will require formal evolutionary models of the adaptive dynamics of such learning-domain asymmetries. Once precise predictions have been derived, future developmental investigations could test the possibility that domain sensitivity is a coevolved adaptation of a cultural species.

It bears mentioning that our participants saw two things simultaneously: bystanders looking towards one model and away from the other one; either or both of these could have driven our effect. We have emphasized the former here for simplicity, but in fact both mechanisms are consistent with our results and with the predictions made by CGC theorists, which require only that bystanders' attention influence cultural learning. Further work disambiguating the relative weights of these influences would be valuable and interesting.

Given recent results on ostensive pedagogy (Csibra & Gergely, 2009; Gergely & Csibra, 2005; Topál, Gergely, Miklosi, Erdohegyi & Csibra, 2008, 2009), it also bears mention that, while both our models gave ostensive learning cues (they looked at the camera before each testing clip), our bystanders did not; they simply looked at models. That is, children seem to infer prestige information from the attention of bystanders, without bystanders explicitly cueing that "this is a learning opportunity".

Although we tested an a priori evolutionary hypothesis, we cannot conclude from this study alone that children are prestige-biased cultural learners because their prestige-biased ancestors were favored by natural selection. Children's observed prestige bias may result from cognitive mechanisms selected for entirely different ends. Nonetheless, in the absence of a detailed alternative account of these patterns, this study contributes to a growing body of evidence supporting this CGC's prediction.

A comprehensive understanding of the role of prestige bias in cultural transmission has the potential to shed light on many modern psychological and social phenomena besides children's learning. Formal modeling of biased cultural transmission can readily generate predictions about higher-level sociological phenomena, such as the diffusion of innovations (Henrich & Boyd, 2001), the emergence of ethnic groups (McElreath et. al. 2003) or the properties of modern religions (Boyer, 2001; Henrich, 2009). Prestige bias might also contribute to explanations at a sociological level; for instance, why famous individuals' suicides increase suicide rates in populations of similar age and ethnicity, using similar methods (Fu & Yip, 2007; Stack, 1987), or how it is that people can become "famous for being famous" without any valuable skills, notable success, etc.

Future laboratory investigations will clarify the proximate mechanisms underlying prestige bias and further examine its widespread implications for cultural evolution. In particular, we feel there is scope for further work that explores other domains in which prestige biases learning and the relationships between these domains. Working across diverse human societies, empirical investigations on this topic should probe the interaction of prestige with other cues of model quality such as age, self-similarity, and ethnicity; vary features of the bystanders, especially their age and cues of group membership such as ethnicity and accent, to see whether children are more likely to imitate the model preference of bystanders more "like them"; and measure the rate at which this effect strengthens with mounting evidence of preferential bystander attention.

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