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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 recently begun using subtle 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: *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 three- and four-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. What's more, this effect appears domain-sensitive: in Study 2 when bystanders preferentially observed a prestigious model using artefacts, she was more often learned from on subsequent artefact-use tasks (odds almost 5 times greater) but not food-preference tasks, while the reverse was true of a model who received preferential bystander attention while expressing food-preferences.

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 behavioural heuristics, etc.) have broad relevance to understanding human cognition and behaviour. 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 (that is, 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 three- and four-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 (Gergely, & Csibra, 2005; Csibra & Gergely, 2009), cognitive fluidity (Mithen, 1996), and epistemic vigilance (Sperber, 2006) facilitated by 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 (Richerson & Boyd, 2005; Kendal, Giraldeau & Laland, 2009; Eriksson, Enquist & Ghirlanda, 2007; Cavalli-Sforza & Feldman, 1981; Mesoudi, 2009).

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 (Richerson & Boyd, 2005; Mesoudi, 2009; Laland, 2004; Galef & Whiskin, 2008a; Powell, Shennan, & Thomas, 2009; for a review, see Richerson & Boyd, 2005; Henrich & Henrich, 2007: 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 capitalising 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 learners¹. This difference results when learners prefer to attend to and hang around their more skilful peers, avoid attending to less skilful 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), behavioural 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; 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,

¹ In our experiment the "prestigious model" is distinct only by receiving bystanders' preferential gaze.

Akmal, & Frampton, 2010; Jaswal & Malone, 2007; Sabbagh & Baldwin, 2001), artefact-makers about their artefacts (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 (McElreath, Boyd & Richerson, 2003; Boyd and Richerson, 1987) 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 study directly tests for prestige-biased cultural learning in three- and four-year-olds. To date, the developmental evidence most relevant to prestige-bias comes from Fusaro and Harris (2008). Their four-year-old participants saw two models labelling 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 didn't 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 or conformist-bias² – a distinct learning

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

mechanism (Henrich & Boyd, 1998; Eriksson, Enquist & Ghirlanda, 2007; Kendal, Giraldeau & Laland, 2009) 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. Further, linguistic disagreements between models may be a cue to ethnic differences, which have also been formally predicted (McElreath, Boyd & Richerson, 2003) and shown (Kinzler, et al., 2007; Shutts, et al., 2009) to bias children's behaviour.

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 potentially costly behavioural domains:** they will learn preferences and behaviours, not just language, including those in potentially costly domains like food and drink choices.

punishment. Conformist-bias is also indirectly supported (that is, these were not designed to test this evolutionary prediction, but their results support it) by developmental evidence (Corriveau & Harris, 2009).

Study 1

Method

Participants

We measured the selective learning of 23 children (mean age = 50.4 months, SD=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.

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-second “Test” clips, where those two models demonstrated different behaviours, 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 Figure 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 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 seconds stood between and slightly behind the models, angled toward and watching the prestigious model.

Artefact Use: Models interacted with a novel toy by delightedly using either coloured 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 labelled 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?"

Results and Discussion

Since participants always made binary choices, with each choice representing an implicit endorsement of one model as preferred, we analysed 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, we conducted log likelihood ratio tests³; 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 didn't 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 analyse their effect on participants' proclivity to prestige-bias.

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

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".

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 ($CI_{.95} = [1.22, 4.58]$, $p = .01$) 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.

Is learning prestige-biased across domains?

Participants witnessed models receiving unequal attention from two bystanders while demonstrating different techniques for using an artefact, however our non-explicit tests fell into three domains: (1) artefact use (involving a different artefact from the cuing scene); (2) food and drink preferences (that is, the food and drink measures taken together as indexing a single construct); and (3) linguistic labels for novel objects. In both behavioural domains (i.e., artefact and food/drink), children were significantly more likely to learn from the prestigious model; the odds of them doing so were 8.25 ($CI_{.95} = [1.15, 59.00]$) times greater for artefact use and 4.09 ($CI_{.95} = [1.02, 16.38]$) times greater for food and drink preferences pooled together. When analysed 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 ($OR=.57, p=.60$).

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 ($p_{LLRT} = 0.80$).

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.

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'd received ten seconds of bystanders' attention (gaze) than one who hadn't.

While demonstrating the basic effect, this study also raised some pressing questions. Our artefact-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, 2005). 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 two was designed to control for experimental fatigue and address the question of domain sensitivity by manipulating the domain in which prestige was cued.

Study 2

Method

Participants

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

Procedure

In Study 2 we systematically counterbalanced the domain in which prestige (specifically: differential bystander attention) was established between artefact-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. Earlier test trials were designed to minimise the feedback participants received on whether they'd 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 artefact-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 artefacts or demonstrating food and drink 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 artefact-use techniques or food-preferences by making a choice between two options. The following are detailed descriptions of these components, in order of appearance.

Initial Cueing Scenes:

In each condition, participants saw two cues from a single domain (artefact or food) presented in the following order.

Artefact, Drawing: Bystanders watched models drawing with coloured crayons on paper. The drawings were indistinguishable on the video.

Artefact, Building: Bystanders watched 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.

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'd seen demonstrated. The order in which they saw the tests and the order in which models appeared were counterbalanced between participants.

Artefact, 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 seconds, they were prompted 'Which of these do you think you should use?' Participants did not receive feedback on whether they'd 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 yummiest?' Again, participants were not given any feedback on their choice or allowed to sample the drink.

Reminder Cue:

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

Artefact, 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.

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.

Artefact, 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 didn't have information about the success of each technique, clips terminated just before models actually used 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 themselves (so participants couldn't 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 one, but you can only choose *one*. Which one would you like?' In either container children found a fruit-flavoured gummy candy, which they were allowed to eat.

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?'

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-centred our variables to make this interpretation straightforward.

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 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.

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 analyse this effect, each using a variable which encodes whether the test was in the same domain (artefact 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 ($b=1.54$, $SE=0.49$, $p<0.01$) and effect-size estimate in terms of the models: being prestigious improved a model's odds of being learned from by 4.75($CI_{.95} = [1.91, 11.8]$) times on same domain tests, but not ($p=0.96$) on cross domain tests.

A conceptually simpler approach for examining this is to add 'same 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 ($CI_{.95} = [1.30, 3.36]$) times greater. This effect shifted the probability of learning from the prestigious model from about 52% ($p=0.72$) on cross-domain tests to about 69% ($p<0.001$) on same domain tests. These effects are illustrated visually in Figure 2, where it is apparent that though food tests trended non-

significantly towards prestige-bias when children saw artefact cues, artefact tests showed the opposite trend when children saw food cues. Each individual test showed the same domain-sensitivity effect (see Figure 3), though when analysed independently this difference only reached conventional levels of significance for the geo-board test ($p=.04$).

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 ($p=.45$).

Did children explicitly recall who bystanders had attended to?

No. Only 22 (46%) of our participants were able to recall who bystanders had looked at, the remainder either said they didn't 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 ($p=.64$).

Discussion – Study 2

This study replicates and extends Study 1, constituting 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. This effect is particularly interesting given that our participants weren't able to reliably, explicitly recall which model had received bystander attention, nor were their

explicit preferences for which model they'd like as a playmate influenced by our cuing of prestige.

General Discussion

Our findings provide support for the existence of a domain-sensitive prestige-bias in children's learning: children's preferences for cultural models were 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 behavioural phenotype predicted *a priori* by CGC theorists; that is, on the basis of evolutionary reasoning undertaken prior to this phenotype being observed. Importantly, CGC predicts the behavioural 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 then one would expect that representation to precipitate a bias to learn from that model regardless of the learning domain. Though 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. That children

don't 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 increase with the age of our subjects, suggesting that it may be in place or fully developed prior to three years of age. CGC's prediction is consistent with either an innate⁴ prestige bias or innate, evolved cognitive mechanisms which make acquiring prestige-bias by individual learning substantially more likely. Our results are also consistent with either of these possibilities, though future work with younger children might help tease them apart. Though 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.

We witnessed an asymmetric pattern of domain sensitivity: in both studies our food and drink preference were prestige-biased when children saw artefact-use cues (though this only reached conventional significance in the first study), however, artefact-use preferences were not prestige-biased by food cues nor was language learning biased following artefact-use cues. This raises the interesting possibility that children's inference about model quality could exploit an asymmetric map of the relationships between learning domains. Future work could test this possibility and begin to map these relations. At present we speculate that

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.

children may form cognitive representations of the correlations between skill domains which inform their model choices. Such correlations do exist, because:

- a) skill at certain tasks (for example: foraging and dietary choices, but not weight-lifting) relies on the same underlying traits (to continue the example: local ecological knowledge), generating symmetric relations, and
- b) (in)competence at (easy)hard tasks implies (in)competence at (harder)easier ones but not necessarily easier(harder) ones, generating asymmetric relations.

If such correlations were sufficiently regular in our evolutionary past, selection may have shaped cognitive mechanisms that more readily recognise them, generating regular patterns of asymmetric, domain-sensitive biased learning in modern children.

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 emphasised 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 (Gergely, & Csibra, 2005; Csibra & Gergely, 2009; Topál et al., 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'.

Though 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 favoured 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 modelling of biased cultural transmission can readily generate predictions about higher-level sociological phenomena, such as the diffusion of innovations (Henrich, 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 individuals, using similar methods (Fu & Yip, 2007; Stack, 1987).

Future 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 to explore other domains in which prestige biases learning and the relationships between these domains, to probe the interaction of prestige with other cues of model quality such as age, self-similarity, and ethnicity, and to measure the rate at which this effect strengthens with mounting evidence of preferential bystander attention.

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FIGURES FOR CHILDREN'S PRESTIGE-BIASED LEARNING



FIGURE 1. Scenes that children saw in study 1 in the order they saw them.

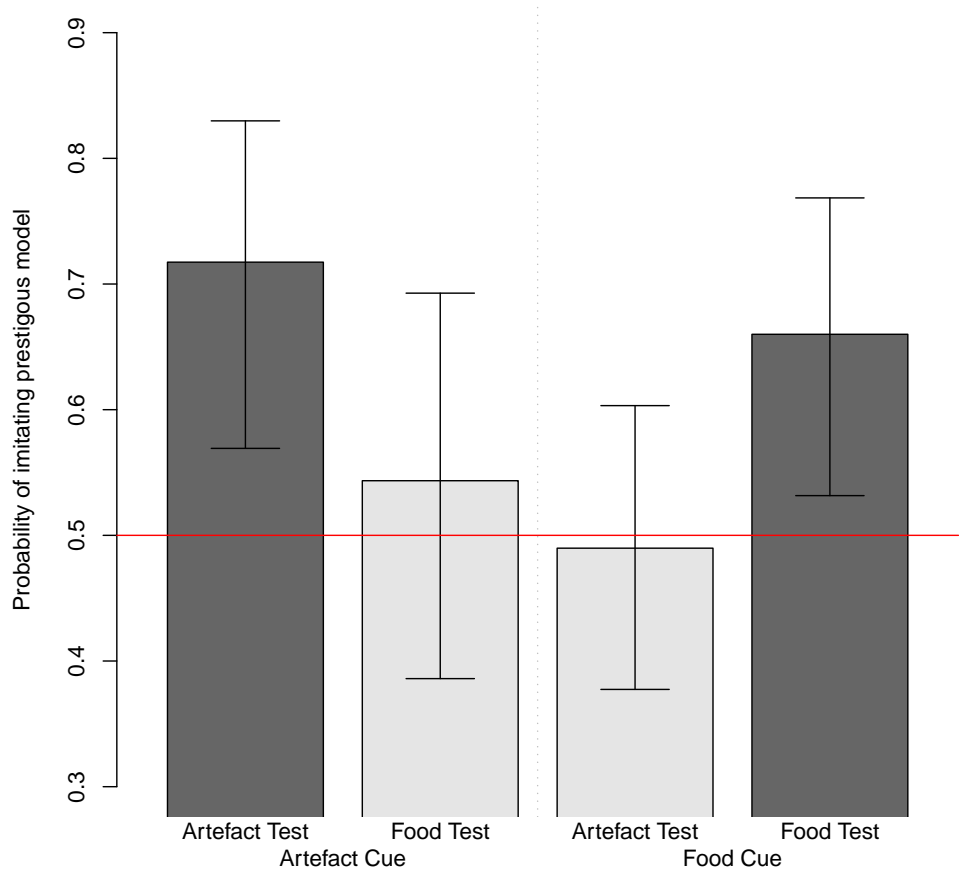


FIGURE 2. Probability of children imitating the prestigious model with 95% confidence intervals, in the same domain as the prestige Cue (darker bars) and the other domain (lighter bars)

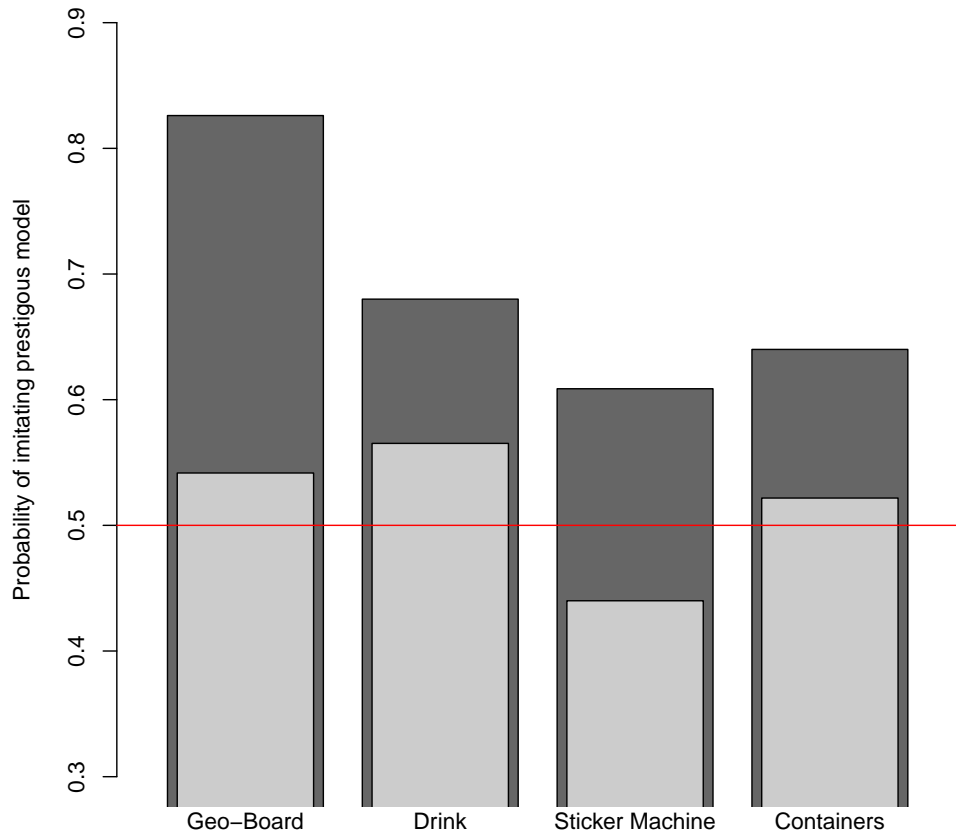


FIGURE 3. Probability of children imitating the prestigious model on each test, when they had seen a cue in the cross domain (lighter bars) or the same domain (darker bars). The only test for which this difference was significant when analysed alone was the Geo-board ($p=.04$).

TABLES FOR CHILDREN'S PRESTIGE-BIASED LEARNING

FULL MODELS - LOGISTIC REGRESSION COEFFICIENTS (STANDARD ERRORS)

<i>Predictors</i>	<i>Statistical Models</i>			
	Pooled	Artefact	Food & Drink	Labelling
<i>Prestige</i>	.90 (.37)**	2.60 (1.30)*	1.42 (.67)*	-.57 (1.07)
<i>Sex</i>	.0 (.34)	-1.33 (1.43)	1.30 (.73)^	-2.90 (1.48)*
<i>Order</i>	-.56 (.33)^	-2.49 (1.50)^	-.42 (.57)	-1.94 (1.36)
<i>Age</i>	-.02 (.03)	-.08 (.14)	.03 (.06)	.01 (.10)
<i>pLLRT</i>	.16	.04	.14	.13
<i>n</i>	100	23	44	23

^: $p < .1$; * : $p < .05$; ** : $p < .01$

Table 1

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* the sex of the participant, *Order* encodes which actor appeared first and *Age* the participant's age in months. *pLLRT* 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.

PARSIMONIOUS MODELS - LOGISTIC REGRESSION COEFFICIENTS (STANDARD ERRORS)

<i>Predictors</i>	<i>Statistical Models</i>			
	Pooled	Artefact	Food & Drink	Labelling
<i>Prestige</i>	.86 (.33)**	2.11 (1.0)*	1.4 (.7)*	
<i>Sex</i>			1.5 (.7)*	-1.84 (.98)^ ^
<i>pLLRT</i>	.03	.02	.04	.04
<i>n</i>	100	23	44	23

^: $p < .06$; * : $p < .05$; ** : $p < .01$

Table 2

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* the sex of the participant. *pLLRT* 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.

STUDY 2 - PRESTIGE MODELS

<i>Predictors</i>	<i>Statistical Models</i>			
	Basic	Parsimonious Basic	Interaction	Parsimonious Interaction
<i>Prestige</i>	0.75(0.35)*	0.74(0.31)**	1.56(0.47)**	1.64(0.43)**
<i>Sex is Male</i>	0.32(0.33)		0.33(0.35)	
<i>Age</i>	0.00(0.01)		0.00(0.01)	
<i>Order</i>	0.35(0.34)		0.37(0.35)	
<i>Cue is Food</i>	0.25(0.32)		0.27(0.33)	
<i>Test is Food</i>	0.11(0.26)		0.12(0.24)	
<i>Cross-Domain</i>			1.01(0.37)**	1.01(0.37)**
<i>Cross-Domain * Prestige</i>			-1.54(0.49)**	-1.51(0.48)**
<i>PLLRT</i>	.04	.01	.002	.001

* : $p < .05$; ** : $p < .01$

Table 3

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, *Age* 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, false otherwise. *PLLRT* is the result of a log-likelihood ratio test of the regression's goodness of fit. All regressions are based 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.

STUDY 2 - COVARIATE MODELS

<i>Predictors</i>	<i>Statistical Models</i>		
	Basic	Domain	Parsimonious Domain
<i>Intercept</i>	0.42(0.16)**	0.81(0.21)**	0.79(0.21)**
<i>Model</i>	0.43(0.36)	0.45(0.37)	
<i>Sex</i>	0.01(0.34)	0.01(0.35)	
<i>Age</i>	0.00(0.01)	0.00(0.01)	
<i>Order</i>	0.27(0.34)	0.27(0.35)	
<i>Cue</i>	-0.22(0.32)	-0.23(0.33)	
<i>Test</i>	0.02(0.26)	-0.03(0.25)	
<i>Cross-Domain</i>		-0.74(0.24)**	-0.73(0.24)**
<i>PLLRT</i>	.7	.07	.002

** : $p < .01$

Table 4

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* whether the participant was male, *Order* encodes which actor appeared first, *Age* 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, false otherwise. *PLLRT* is the result of a log-likelihood ratio test of the model's goodness of fit. All test are based 191 observations whose non-independence was explicitly modelled by computing Huber-White clustered robust standard errors.

For ease of interpretation all variables are mean-centred, besides *Cross-Domain*. This allows the logistic intercept $\{+$ the *Cross-Domain* coefficient $\}$, to be directly transformed $(\frac{1}{1+e^{-\beta_0}})$ to the proportion of participants who imitated the prestigious model on tests in the same $\{\text{cross}\}$ domain.