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Who do children copy? Model-based biases in social learning

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Abstract

This review investigates the presence of young children's model-based cultural transmission biases in social learning, arguing that such biases are adaptive and flexible. Section 1 offers five propositions regarding the presence and direction of model-based transmission biases in young children's copying of a model. Section 2 discusses the cognitive abilities required for differing model-based biases and tracks their development in early childhood. Section 3 suggests future areas of research including considering the social aspect of model-based biases and understanding their use within a comparative perspective.

Keywords: Social learning, model-based biases, cultural transmission, social cognition, trust.

1 Social learning is ubiquitous in humans, and fundamental to children's development,
2 but alone cannot explain the unique stability and diversity of human culture. Research from a
3 plethora of academic disciplines investigating cultural evolution has escalated in recent years
4 (Boyd, Richerson, & Henrich, 2011; Whiten, Hinde, Laland, & Stringer, 2011), increasing
5 our understanding of the circumstances that facilitate social learning. Theoretical models of
6 cultural evolution predict the evolution of flexible strategies enabling avoidance of unreliable
7 or redundant information, and influencing the circumstances under which individuals copy
8 others (Boyd & Richerson, 1985). Thus, social learning is not seen as inherently beneficial
9 and must be used selectively in the context of the observer's environmental and model-based
10 cues (characteristics of a demonstrator exhibiting a behaviour pattern). The use of such cues
11 in guiding behaviour is known as 'cultural transmission biases' (Boyd & Richerson, 1985,
12 also termed 'social learning strategies'; Laland, 2004) and allows populations to approach
13 adaptive optima much faster than they otherwise would under individual learning (Mesoudi
14 & O'Brien, 2008) or unbiased social learning in which individuals acquire variants according
15 to the frequency at which they are practiced (Rendell et al., 2011).

16 The adaptive value of model-based biases have been investigated in disciplines such
17 as evolutionary biology, anthropology and non-developmental domains of psychology.
18 Model-based biases have been described as 'who' biases (Laland, 2004), indirect biases
19 (Boyd & Richerson, 1985) and context dependent model-based biases (Henrich & McElreath,
20 2003). Within developmental psychology it has long been established that it is important to
21 understand whom children learn from, and that children's learning entails 'an active construct
22 of the model by the individual' (Užgiris, 1981, p. 2). As children develop they constantly
23 witness alternative methods of achieving a goal. This has been mirrored in experiments where
24 children witness divergent information from different models relating to tool-use (Wood,
25 Kendal, & Flynn, in prep), and labels for elements in the environment (Koenig, Clément, &

26 Harris, 2004). When faced with divergent information it would be adaptive to select and
27 reproduce the information that achieves the outcome most suited for one's needs, but this can
28 be complex. Models have different characteristics that influence our choice, including their
29 previous performance, knowledge state, age, sex and social status. Furthermore, observers'
30 own characteristics may influence who is the 'best' model for them. The potential list of
31 relevant characteristics is endless and a naïve individual needs to evaluate these
32 characteristics so that the behaviour of the most appropriate model, potentially providing the
33 most useful and adaptive behaviour, is adopted.

34 This review uses an evolutionary approach to understand how model characteristics
35 bias the likelihood that an observing child copies modelled behaviour. We define copying as
36 a broad behaviour of a child either matching the behaviour of a model or preferentially
37 selecting one model's behaviour (e.g. a novel object is given a different word label by two
38 models and when prompted, the child repeats one of the models' word labels). Copying is an
39 important mechanism in children's social learning. Whilst focusing on instances of copying a
40 model, we acknowledge that children are able to learn behaviour without necessarily
41 reproducing every aspect of a demonstration (Bekkering, Wohlschläger, & Gattis, 2000;
42 Flynn & Whiten, 2008; Williamson, Meltzoff, & Markman, 2008) and that copying a model
43 may serve a function beyond simply learning behaviour (Over & Carpenter, 2011). In Section
44 1 we argue that model-based biases enable children to gain the most useful information
45 pertaining to their environment; hence a model-based bias may be viewed as an adaptive
46 cognitive tool. Throughout this review, adaptive means that the model-based bias contributes
47 to an individual's survival by providing them with more useful behaviours within their
48 environment, or enables avoidance of unreliable or redundant information, than if such a
49 model-based bias did not exist. In Section 2 we describe the developmental shift in the

50 implementation of model-based biases, demonstrating increasingly flexible implementation.
51 We conclude in Section 3 by discussing future considerations and directions.

52

53 **Section 1: The adaptive value of model-based biases**

54 In this section we make five propositions regarding the adaptive value of model-based biases.

55 To begin, we examine children's biases towards models whose behaviour indicates their
56 desire to transfer information, namely children's receptiveness to pedagogical cueing.

57 Second, we consider children's ability to evaluate and copy the most proficient individual
58 before moving on to discussing characteristics that identify models as belonging to groups
59 with certain reputations that may guide children's copying. Fourth, we argue that the more
60 similar a model is to a child, the more suitable s/he might be as a model, before finishing by
61 discussing children's biases towards models that are prestigious.

62

63 **Proposition 1: Children are biased towards those who intend to teach**

64 Csibra and Gergely (2009) argue that children have an innate predisposition for
65 receptiveness towards people's ostensive signals indicating that the person is trying to
66 communicate relevant information. These cues may include pointing, eye contact, and verbal
67 directions. If a person is actively trying to communicate information then, generally, the
68 person is communicating information about the environment that they believe will assist the
69 observer. Being sensitive to a model's ostensive cues is adaptive because it enables children's
70 attention to be drawn to important aspects of the environment. The sensitivity to ostensive
71 cues is present from infancy, for example fourteen-month-olds search where they see
72 someone point (Behne, Carpenter, & Tomasello, 2005) and copy the unusual action of
73 turning a light on with their head if told by the model "I'm going to blick the light" as
74 opposed to just "Look at this" (Chen & Waxman, 2013). This sensitivity influences which

75 models individuals copy; children copy a model more when s/he stoops to the child's level,
76 leans in, makes eye contact and talks engagingly (Brugger, Lariviere, Mumme, & Bushnell,
77 2007), gives verbal cues about the importance of actions (Southgate, Chevallier, & Csibra,
78 2009) or performs actions in a seemingly purposeful, rather than accidental manner
79 (Carpenter, Akhta, & Tomasello, 1998; Gardiner, Greif, & Bjorklund, 2011). Indeed this
80 receptiveness to pedagogical cueing is so strong it can limit exploratory play and discovery
81 (Bonawitz, Shafto, Gweon, Goodman, Spelke, & Schulz, 2011). Thus, children are receptive
82 to pedagogical cueing and are biased towards copying models who attempt to share
83 information about the environment.

84

85 **Proposition 2: Children are biased toward copying the most proficient models**

86 A model's success in a particular context indicates his or her ability to deal with that
87 environment, therefore a successful model's behaviour is the most adaptive behaviour to
88 adopt. There is evidence that infants are able to discriminate between models who act
89 competently or incompetently (Zmyj, Buttellmann, Carpenter, & Daum, 2010) and seven-
90 year-old children preferentially copy children rated by an experimenter as being competent
91 rather than less competent (Brody & Stoneman, 1985). Likewise, the 'Trust' paradigm
92 (Harris, 2007; Koenig & Harris, 2005a), whereby children are introduced to one reliable
93 model (e.g., labels a ball, "ball") and one unreliable model (e.g., labels a ball, "shoe"), has
94 demonstrated that, from infancy to six-years-old, children consistently copy reliable models
95 over unreliable labellers for novel words (Koenig et al., 2004; Koenig & Harris, 2005b;
96 Vázquez, Delisle, & Saylor, 2012) and artefact use (Birch, Vauthier, & Bloom, 2008; Zmyj et
97 al., 2010). The labelling of artefacts are more likely to be copied from models who self-
98 declare they know what is right (declaring, "this is a spoon") than models who are uncertain
99 ("*I think* this is a fork"; Jaswal & Malone, 2007) and models who are labelled as smart rather

100 than not smart (Lane, Wellman & Gelman, 2012). Thus, children are able to discern the
101 proficient model and are biased towards the information this model provides.

102

103 **Proposition 3: Children are biased toward copying models belonging to a group which**
104 **has a reputation for being proficient**

105 Employing model-based biases regarding an individual's proficiency is costly in
106 terms of time and cognitive processing, as it requires an assessment of the behavioural history
107 of a model. Instead, it is more efficient for an individual to be biased towards characteristics
108 of models that are easily identifiable, often indicating an individual's membership to a group.
109 This group may have a different reputation for proficiency from another group leading to
110 model-based biases. For example, a salient characteristic indicating group membership is age.
111 A 'copy older over younger models' strategy seems adaptive because older individuals have
112 had more experience with the environment and, by their continued existence, have made
113 successful choices within the environment. Such age biases exist. Fifteen-month-olds are
114 more likely to copy videotaped target acts when presented by an adult versus a two-year-old
115 child (Seehagen & Herbert, 2011). Younger (one- to two-year-olds) siblings copy the
116 spontaneous social behaviours of their older (three- to five-year-old) siblings far more than
117 the other way around regardless of age gap or sex differences (Abramovitch, Corter, &
118 Pepler, 1980; Pepler, Abramovitch, & Corter, 1981). Three- and four-year-olds preferentially
119 copy information provided by an adult over a child for novel object labelling (Jaswal &
120 Neely, 2006), and object less when a puppet copies an adult, rather than a child model
121 demonstrating alternative actions on a novel game (Rakoczy, Hamann, Warneken, &
122 Tomasello, 2010). Also, seven- and eight-year-olds copy the food choices of older rather than
123 younger children (Brody & Stoneman, 1981). This bias towards copying older individuals is
124 also seen in the reproduction of causally irrelevant actions by children; when models use

125 causally-inefficient tools, adults are more likely to be copied than children (Elekes & Kiraly,
126 2012), two- and three-year olds do not copy the irrelevant actions demonstrated by a peer to
127 the same extent as when demonstrated by adult models (Flynn, 2008; Horner & Whiten,
128 2005), and three- and five-year-olds copy relevant actions of both child and adult models but
129 only faithfully reproduce the irrelevant actions of adults (McGuigan, Makinson, & Whiten,
130 2011; Wood, Kendal, & Flynn, 2012). Potentially, children assume that increased age
131 indicates increased proficiency and use this bias to guide their copying (although see Section
132 2 for instances where this does not happen).

133

134 **Proposition 4: Children are biased toward copying models that resemble themselves**

135 Individual differences result in individualised needs within an environment. These
136 differences can influence children's proclivity to gain information from a model that is most
137 similar to them, an 'observer-specific model-based bias'. This observer-specific bias may
138 happen at a genetic, physiological or cultural level. For example, four- and five-year-olds
139 generally accepted their mother's claims over those of a stranger (Corriveau et al., 2009)
140 indicating that children may select information from those more genetically related to them.
141 Familiarity is a confound to this interpretation, yet familiarity itself can be a marker of in-
142 group membership and infants copy more actions of a familiar, compared to an unfamiliar,
143 model (Learmonth, Lamberth, & Rovee-Collier, 2005). Likewise, three- to five-year-old
144 children, given conflicting artefact labels and functions from a known or unknown teacher,
145 preferentially copy the known teacher (Corriveau & Harris, 2009b). Children also copy the
146 choices of familiar models when choosing personal preferences or labelling artefacts (Shutts,
147 Kinzler, McKee, & Spelke, 2009) and in tool use tasks (Buttelmann, Zmyj, Daum &
148 Carpenter, 2012; Seehagen & Herbert, 2011). This preference for copying familiar models is
149 adaptive because the child and the model have definite overlaps in their environment whereas

150 the history of the stranger is unknown and, therefore, the information they provide may not
151 be relevant for the child's particular environment.

152 Another salient physiological group difference is sex and whilst sex is not necessarily
153 correlated to ability within our environment, children may be influenced by cultural sex-role
154 norms. Indeed, eighteen-month-old children discriminate between stereotypical male and
155 female artefacts (Serbin, Poulin-Dubois, Colburne, Sen, & Eichstedt, 2001). Likewise, three-
156 year-olds copy the preferences of same-sex (over different-sex) child models for personal
157 preferences of novel food, clothes, toys and games (Frazier, Gelman, Kaciroti, Russell, &
158 Lumeng, 2011; Shutts, Banaji, & Spelke, 2010) and copy the novel word label from a same
159 sex rather than opposite sex adult model when both adults were equally reliable (Taylor,
160 2013). This adoption of sex-specific behaviour may provide children with relevant
161 information pertaining to their physiological needs or it may enable them to learn behaviours
162 expected of their sex by their cultural group.

163 Learning other appropriate behaviour for one's cultural group seems fundamental to a
164 child's development and there is evidence for a bias towards copying those belonging to the
165 same cultural group. Twelve-month-olds show a personal preference for foods endorsed by a
166 speaker of their native language versus a model speaking a foreign language (Shutts et al.,
167 2009). Likewise, five- and six-month-old infants attend more to a model speaking natural
168 English over a model speaking 'reverse' English (the audio was played backwards) or a
169 foreign language, and infants are also biased towards selecting a toy endorsed by a model
170 speaking their native language (Kinzler, Corriveau, & Harris 2011) or using a native accent
171 (Kinzler, Dupoux, & Spelke, 2007). Language is one of the most basic markers of cultural
172 identity and, as seen with familiarity, a bias towards copying models who share your culture
173 may be adaptive because the cultural similarity indicates a shared environment, and,
174 therefore, the behaviour of the most similar model may be the most relevant.

175

176 Proposition 5: Children are biased towards copying models with high status

177 Status incorporates two forms of social power; *dominance*, defined as an ability to
178 acquire and monopolise resources over others, often through threatened or actual antagonism,
179 and *prestige*, defined as status through non-agonistic means achieved through excelling in
180 valued domains. Henrich and Gil-White (2001) note the importance of differentiating these
181 two forms of status, which have their ‘own distinct psychology, selected for by distinct
182 evolutionary pressures’ (p. 166). Humans can exhibit status through non-agonistic means and
183 attainment of high prestige may reflect an individual’s superior ability to deal with his/her
184 physical or social environment. The behaviour of high-status individuals, whether the status
185 was acquired through skill or force, may thus be adaptive. In turn, it would be adaptive to
186 copy models of high status, although such an adaption may result in copying behavioural
187 traits that do not relate to the attainment of higher status (Mesoudi & O’Brien, 2008), hence
188 the term ‘indirect bias’ (Boyd & Richerson, 1985).

189 Teacher ratings of social status and dominance of children correlate with observable
190 characteristics, such as the age of a child (Grusec & Lytton, 1988), his/her size, and the
191 number of wins in agonistic encounters with other children over resources (Pellegrini et al.,
192 2007). Flynn and Whiten (2012) investigated both dominance and prestige in pre-school
193 children’s social learning. There was evidence of a status-based model-based observation bias
194 in these children; in a naturalistic, open diffusion setting with a novel puzzle-box, older
195 children were watched more than younger children, popular children were watched more than
196 less popular children, and more dominant children were watched more than less dominant
197 children. This observation bias indicates a potential copying bias of more prestigious
198 individuals. As dominant children did not monopolise the task, it seems they were watched
199 out of choice. Further, children were more likely to watch task manipulations made by peers

200 they stated that they ‘liked’ rather than peers they stated that they did ‘not like’. Likewise,
201 McGuigan (2013) found that the higher the status of the model (the child’s head teacher
202 versus a known researcher) the greater the number of irrelevant actions were copied.

203 Whether a model is observed by others may, in itself, be a marker of prestige; four-
204 year-old children use bystanders’ silent reactions to models such that a model who was
205 ‘endorsed’ by bystanders through nods and smiles was copied more for labelling novel
206 artefacts than a model whose behaviour was met with negative bystander reactions (Fusaro &
207 Harris, 2008). This endorsement effect occurs even when the bystander attendance is neutral
208 in comparison to an ignored model (Chudek, Heller, Birch, & Henrich, 2012). Children are
209 receptive to the status of others and are biased towards copying those who have higher status
210 both in terms of dominance and prestige. It would be fruitful to explore the nature of the
211 relation between model status and often associated characteristics, such as proficiency and
212 age, to discover what factors contribute towards prestige. Likewise, to investigate whether
213 biased copying from prestigious models is, in some circumstances, limited to behaviour
214 which potentially contributes to the attainment of prestige, rather than being indiscriminate in
215 this regard as theoretically assumed (Boyd & Richerson, 1985).

216

217 **Summary**

218 We have outlined five propositions relating to the presence and adaptive value of
219 model-based biases. Indeed, the propositions outlined can be adapted to make testable
220 predictions about model-based biases. For example, in line with Proposition 1 we predict that
221 any model who, through verbal or non verbal means, communicates an intention to teach will
222 be more likely to be copied than a model who provides no cues or non-pedagogical
223 communication. Likewise, we predict that, in line with Proposition 3, groups that have a
224 reputation for being more proficient will be copied more than comparative groups. Whilst this

225 section focussed on age we believe that other groups relating to, for example, profession,
226 level of education or expertise, could illicit the same model-based biases.

227 The evidence presented demonstrates that children monitor the characteristics or
228 behaviour of others and use this to guide their own behaviour. Such abilities drive children to
229 copy others, hence socially learn, in a discriminating manner. This behaviour goes beyond
230 simply copying, as it is *biased* copying and it is this bias which makes copying adaptive. The
231 skills required for the implementation of biases are varied. Some model characteristics, such
232 as a model's age and sex, are salient whilst others, such as proficiency and professed
233 knowledge state, are more subtle. Evaluation of these more subtle cues requires the
234 development of certain cognitive skills, such as an ability to track behaviour and understand
235 the knowledge states of others. The next section presents some of the cognitive skills that
236 improve the application of model-based biases and discusses their development in line with
237 the findings from the social learning literature.

238

239 **Section 2: The development of cognitive skills enabling model-based biases**

240 This section reflects on some cognitive skills required in two periods of child development,
241 infancy and early childhood, which enable and assist in implementing model-based biases.
242 The cognitive skills described here are relatively high-level and based on empirical papers
243 detailing model-based biases. Therefore, lower-level cognitive processes, such as working
244 memory, categorisation or language development are not discussed, although future work
245 addressing the influence of these processes on model-based biases seems pertinent. Cognitive
246 skills develop throughout infancy and early childhood and this development affects the use of
247 model-based biases. We argue that these developing cognitive skills enable children to
248 flexibly employ model-based biases in response to environmental and behavioural cues. This

249 flexibility is important because it allows children to continually source and copy the ‘best’
250 model even when there are complex, subtle and multiple model characteristics.

251

252 **From Infancy**

253 **Perspective taking.** From infancy children respond differently depending on a
254 model’s visual access to stimuli and, therefore, potentially what the model knows (Koenig &
255 Echols, 2003; Liszkowski, Carpenter, & Tomasello, 2008). This perspective taking may
256 facilitate the earliest forms of a model-based bias of proficiency. For example, a model who
257 saw where a toy was hidden should be more proficient at locating the toy than a model who
258 was unable to see where it was hidden. Such a model is more proficient in the immediate
259 situation, as opposed to having a reputation for being proficient.

260 **Monitoring reactions to the model’s behaviour.** Infants are also able to monitor the
261 reaction of others towards a model’s behaviour. Infants avoid copying an action when
262 unknown adults react negatively to an adult model’s actions (Repacholi, 2009) or show
263 irritation towards the model (Repacholi & Meltzoff, 2007). A similar pattern is found in
264 three- and four-year-olds when the model is a same-aged peer (Frazier et al., 2011) and also
265 with novel word copying in four-year-olds who copy the novel artefact labels of models for
266 whom bystanders react with smiles, more than the labels given by models for whom
267 bystanders react with frowns (Fusaro & Harris, 2008). This ability to take account of the
268 reactions of others could facilitate two model-based biases proposed in Section 1: first, the
269 reactions of others may indicate that the model has performed a behaviour that pleases or
270 displeases others and, therefore, indicates some degree of third-party evaluated model
271 proficiency (proposition 2), and second, the reactions of others may be directed towards the
272 model themselves and this could indicate some level of prestige (proposition 5). Presenting
273 third-party bystanders who disapproved of clearly correctly modelled behaviour will help

274 differentiate between these biases. Either way, the ability to monitor the reactions of others is
275 a useful skill in the implementation of model-based biases.

276 **Considering context.** The best model in one context may not be the best model in
277 another context, and children appear to show flexibility in the model-based biases employed.
278 Six-month-olds are more likely to copy an action demonstrated by their mother over a
279 stranger (the experimenter) in the infants' homes, but in a laboratory this pattern is reversed
280 and they preferentially copy the experimenter (Seehagen & Herbert, 2012). These authors
281 suggest that infants have expectations about the two models' usefulness as teachers; they
282 spend much time with their mothers who demonstrate pedagogical cues in the familiar
283 environment. Conversely, an infant might have experienced unfamiliar people mostly in
284 unfamiliar settings and, thus, have either formed the expectation that unfamiliar people are
285 knowledgeable in unfamiliar environments or display associative learning of unfamiliar
286 models in unfamiliar environments. Such appreciation of context is sophisticated and as these
287 infants were only six-months-old it seems that adapting model-based biases in different
288 contexts is either automatic or learnt in the first few months of life and this flexibility may
289 contribute to the biases adaptive value.

290 Context also affects biases toward copying models belonging to a particular group,
291 such as an age group. One- and two-year-olds generally imitate spontaneous behaviour
292 exhibited by adults more than peers, but the context affects this replication, such that
293 imitation of parents is more likely to consist of motor skills (e.g. tool use) whereas affective
294 behaviours are imitated from siblings and peers (Kuczynski, Zahn-Waxler, Radke-Yarrow,
295 1987). These two types of behaviour (motor skills and affective behaviours) represent
296 different functions, and therefore could elicit different model-based biases. This extends into
297 early childhood; four- to five-year-old children imitate adults more than children and same
298 age peers when an action is novel, but copy a peer over an older child and adult when the

299 action is not novel (Zmyj et al., 2011). In the first context, the function may be to learn a new
300 skill and, therefore, children should be biased towards copying the model who belongs to the
301 more proficient group whereas in the second context, the action is familiar and, therefore, the
302 predominant motivation may be to copy behaviour appropriate for a child, and thus children
303 copy another child. Indeed, when the context is play infants show higher fidelity copying of a
304 three-year-old child versus an adult (Ryalls, Gul, & Ryalls, 2000) and peers over older
305 children and adults (Zmyj, Aschersleben, Prinz, & Daum, 2012), and children also prefer
306 clothes, toys, games and foods endorsed by children over those endorsed by adults (Shutts et
307 al., 2010). Furthermore, in a diffusion chain paradigm, when an adult demonstrated
308 functionally irrelevant actions, in a functionally oriented way, the first child copied these
309 actions but subsequent children parsed out the action of the child model they had witnessed
310 (Flynn, 2008). Conversely, when an adult model demonstrated irrelevant actions in a playful
311 way the behaviour spread; the children copied the child models (Nielsen, Cucchiaro, &
312 Mohomedally, 2012). This implies children assess the context and copy individuals
313 belonging to groups who will be most proficient in that context, so will most aid their
314 interaction with that environment. Alternatively, and as discussed in Section 3, copying may
315 not always be driven by a desire to learn but instead a desire to share a social experience
316 (Užgiris, 1981), or become more integrated with a social group (Over & Carpenter, 2012).

317 Context also influences perceptions of the relative proficiency of one model (or
318 group) over another model (or group). When three- to five-year-olds, presented with stick
319 figure ‘adult’ or ‘child’ models, were asked who would provide more reliable answers to
320 questions, children selected the adult when the questions were within the adult domain, such
321 as the nutritional value of food, but when the subject area was toys children deferred to the
322 child model (VanderBorghet & Jaswal, 2009). An ability to consider the domain of the
323 behaviour alongside the model characteristics is adaptive as it allows for contextual flexibility

324 in behaviour. Moreover, children demonstrate flexibility in their choice, such that when
325 children are informed that a toy is ‘the adult’s favourite toy’ they defer to the adult, rather
326 than a child model, for subsequent information regarding that toy (VanderBorghet & Jaswal,
327 2009). The additional flexibility of understanding that there may be exceptions to a domain
328 appropriate model-based bias is cognitively sophisticated and adaptively biases the child
329 towards the most proficient model in each specific instance.

330 Evaluating context is an important skill in ensuring that model-based biases towards
331 certain models and categories (e.g. adult versus child) may be used flexibly. The flexibility of
332 biases ensure that whilst children have biases towards copying individuals based on their
333 group membership they understand that these groups have different skills involving varying
334 degrees of functional and social relevance for the observing child. Therefore, this flexibility
335 increases the adaptive value of model-based biases.

336

337 **From Early Childhood**

338 **Evaluating a model’s testimony.** Evaluating model testimony is important for
339 proposition 2 (children are biased toward copying the most proficient models). Here we see
340 an example of a cognitive skill that develops throughout early childhood, influencing the
341 discrimination of particular models. Studies involving model testimony have shown that
342 three-year-olds show mixed discrimination of proficient and less proficient models, with
343 evidence of copying the behaviour of the reliable model (Birch et al., 2008; Corriveau &
344 Harris, 2009a) but also a lack of discrimination of accurate over inaccurate informants
345 (Koenig & Harris, 2005b). However, by four to six years, children consistently copy reliable
346 models over unreliable labellers for copying labels for novel objects (Koenig et al., 2004;
347 Koenig & Harris, 2005b; Vázquez et al., 2012) and artefact use (Birch et al., 2008). Six-year-
348 olds also copy reliable labellers over tangential labellers, who are not inaccurate but fail to

349 answer the question, although four-year-olds fail to make such a distinction (Vázquez et al.,
350 2012). Furthermore, three-year-olds have difficulty discriminating between models when the
351 reliable informant is anything other than 100% accurate, whereas four-year-olds are able to
352 make distinctions between a model who was right 75% of the time versus a model who was
353 right 25% of the time (Pasquini, Corriveau, Koenig, & Harris, 2007). Recently, Lucas, Lewis,
354 Pala, Wong & Berridge (2013) have shown an association between specific cognitive skills
355 and evaluation of a model's testimony; children who demonstrated stronger false belief
356 understanding were more likely to copy the model with the more accurate prior testimony,
357 than children with poorer false belief understanding. Whether it is the development of false
358 beliefs per se or the ability to hold in mind multiple constructs at the same time, irrespective
359 of whether they refer to mental states or not, this study shows a clear developmental shift in
360 the use of model based biases. Furthermore, this study highlights the importance of
361 investigating which specific cognitive skills affect model-based biases.

362 **Understanding knowledge states.** Another way in which models can be evaluated is
363 through the use of the model's self-declared knowledge state. Models can express different
364 levels of confidence in their knowledge state by using terms such as 'know', 'think', 'guess'
365 and 'don't know' that present a scale of knowledge confidence. Here, we see increasingly
366 sophisticated understanding of the subtle differences in model self-declared knowledge states,
367 throughout early childhood. For example, children as young as three years are able to
368 distinguish between a model verbally indicating uncertainty ("I think this is a spoon") and
369 one indicating certainty ("This is a spoon") in a novel word copying paradigm (Jaswal &
370 Malone, 2007), but struggle with subtleties of 'know', 'think' and 'guess' (Moore, Bryant, &
371 Furrow, 1989). By four years, children are able to distinguish between 'know' versus 'think'
372 or 'guess' and this improves with age, but until eight years children have difficulty
373 distinguishing between 'think' and 'guess' (Moore et al., 1989). With increasing age comes

374 an expanding vocabulary reflected in an increasing ability to differentiate the subtle
375 differences between model's self-declared knowledge state.

376 Children also adapt to the context of the responses; if a model's hesitant response
377 could be caused by indecision rather than uncertainty, four-year-olds are more likely to
378 accept a model's artefact label (Sabbagh & Baldwin, 2001) so as children develop they
379 become more skilled at evaluating the subtle differences in a model's declared knowledge
380 state. This understanding aids both children's assessment of the potential proficiency of the
381 model. For example, self-declared knowledge can assist in ascertaining the proficiency of the
382 model. Model-based biases involving a model's self-declared knowledge state occur from as
383 young as three years of age, with increased word learning (Sabbagh & Baldwin, 2001;
384 Sabbagh, Wdowiak, & Ottaway, 2003) and irrelevant action reproduction (Wood et al., 2012)
385 following demonstrations from models with declared knowledge versus declared ignorance.

386 **Assessing specialists and generalists.** Evaluation of model testimony might depend
387 upon the speciality of the model's knowledge and the speciality of the to-be-learnt behaviour.
388 Humans have common shared knowledge; we all know the difference between cats and dogs.
389 But we also have specialist knowledge; doctors have expertise in anatomy while farmers have
390 expertise with crops. It follows that if a model fails to show proficiency in shared general
391 knowledge the perception of his/her proficiency should be more negatively affected than if
392 the same model fails to show proficiency in an area of specialist knowledge. Young children
393 are able to make this important distinction, as three- and four-year-olds do not copy a model
394 who specialised in labelling dog species over a neutral model for novel artefact labelling, but
395 a model who wrongly labelled dogs as cats was not chosen over a neutral model (Koenig &
396 Jaswal, 2011). This skill improves with development (Koenig & Jaswal, 2011); whilst four-
397 year-olds do not generalise beyond word knowledge having witnessed a reliable word
398 labeller, five-year-old children generalise that the reliable word labeller will also excel in

399 broader facts (Brosseau-Liard & Birch, 2010). This assessment of specialists and generalists
400 allows children to use more subtle group membership model-based biases rather than more
401 salient distinctions (e.g. age) whilst ensuring that they realise the potential limitations of this
402 group membership.

403 **Tracking prior personal experience and knowledge.** A further evaluative tool
404 available to children is to evaluate models in comparison with their own knowledge. When
405 given no previous chance to interact with a task, five-year-olds will generally copy the
406 irrelevant actions demonstrated, but when they have successful prior interaction with a task,
407 children will copy a new solution demonstrated by a model but parse out the causally
408 irrelevant actions demonstrated by the model (Wood, Kendal & Flynn, 2013). Likewise,
409 three-year-old observers only copy a model until this modelled information results in failure,
410 and four- and five-year-olds improve upon this by only copying models up to the point at
411 which the social information provided by the model conflicts with their personal information,
412 the latter they then favour (Clément, Koenig, & Harris, 2004; Ma & Ganea, 2010).

413 A child's reliance on her personal information is affected by the interplay between the
414 efficacy of her own behaviour and the efficacy of the model's actions, such that children with
415 a difficult prior experience are more likely to imitate an adult's precise means of achieving
416 something, compared to children with an easy prior experience (Williamson et al., 2008).
417 When the model's tool choice conflicts with the child's knowledge of the optimum tool for
418 task completion, children ignore a model's choice unless the model explicitly states that her
419 method is functionally appropriate or when the model's choice is only slightly less efficient
420 than the child's preference (DiYanni & Kelemen, 2008). A developing confidence in one's
421 personal knowledge within a task thus ensures effective evaluation of a model's behaviour.
422 However, over confidence in one's personal information causes the rejection of potentially
423 useful social information (Jaswal, McKercher, & VanderBorgh, 2008); here, children were

424 asked to pick which model gave the right plural or past tense of a novel word. A previously
425 unreliable model's choice was endorsed over a previously reliable model because the
426 unreliable model followed the general grammatical pattern known to the child (add an 's' for
427 plurals and 'ed' for past tense) rather than an irregular change in word. However, what is
428 unclear is whether children accepted the less reliable model's information or whether they
429 just used personal information. Whilst this may lead to a reluctance to accept potentially
430 reliable social information, generally, evaluating the model, relative to ones personal
431 information, generally ensures the critical use of model-based biases.

432 **Calibrating multiple pieces of information or cues.** There are instances whereby
433 children need to evaluate multiple pieces of information about a model and this information
434 may pertain to different biases presented in Section 1. For example, a child may receive
435 information from a proficient child or an incapable adult (Wood et al., 2012). When this
436 occurs, children need to calibrate biases regarding age and proficiency. For example, children
437 favour older, over younger, children when making food choices, only until older models are
438 shown to be less competent than younger models in an unrelated domain (Brody &
439 Stoneman, 1985), and three- and four-year-olds will choose to label a novel object in
440 accordance with a child model, rejecting the adult's label, if the adult's previous behaviour
441 was unreliable (Jaswal & Neely, 2006). Thus, children calibrate a group-based bias of model
442 age against, the potentially more informative, proficiency bias and are more biased towards
443 proficiency. Likewise, when the visual access of a model is more important than a reputation
444 for proficiency five-year-old children will rely more heavily on a model's visual access than
445 prior accuracy when locating a hidden object (Brosseau-Liard & Birch, 2011).

446 Such calibration also occurs with regard to familiarity and proficiency model-based
447 biases. When three- to five-year-old children were given conflicting artefact labels and
448 functions from a known or unknown teacher they copied the known teacher when no further

449 information was provided (Corriveau & Harris, 2009b). However, when the unfamiliar
450 teacher was more accurate than the familiar teacher at labelling familiar objects, four- and
451 five-year-old children moderated their trust of the models, whilst three-year-olds showed
452 little change in behaviour. Thus, calibration is another cognitive skill that shows changes with
453 development. Perhaps three-year-old children have a bias towards familiar adults but have
454 not developed a proficiency model-based bias. Such an explanation is unlikely as from
455 infancy children seem able to judge proficiency (Zmyj et al., 2010; see proposition 2).
456 Alternatively, three-year-old children may be more influenced by the familiarity bias than a
457 proficiency bias, due to a lack of social interactions with unfamiliar individuals. Lastly, three-
458 year-old children may struggle with such calibration in comparison to older children, perhaps
459 due to a poorer working memory. Such a proposal could be tested by assessing the calibration
460 of older individuals when a cognitive load is put upon their working memory.

461 There are other instances where children fail to calibrate; when two models *grasp* at
462 opaque cups, three- to four-year-olds choose the cup grasped by the model who saw which
463 cup held the reward (they choose the ‘seeing’ model), but when both models *point* at the
464 different locations children did not favour the ‘seeing’ model, indicating that the pointing of
465 the ‘unseeing’ model was confusing (Palmquist, Burns, & Jaswal, 2012). For children of this
466 age, the model-based biases towards pedagogical cues (pointing) may be stronger than biases
467 towards models that are proficient due to their visual access, the latter of which is more
468 cognitively complex for the child’s understanding. Likewise, five-year-old children’s
469 imitation of a model is more influenced by the model’s group membership (adult versus
470 child) than the model’s knowledge state (model stating knowledge or ignorance about task
471 completion) even though children of this age are able to correctly identify knowledge state
472 (Wood et al., 2012). This indicates that a failure to correctly calibrate biases is not due to a

473 lack of ability to implement one of the biases but due to the lack of experience a child has had
474 with multiple biases or the cognitive load required within such calibration.

475 Alternatively, young children may understand that a model's self-declared knowledge
476 state is not always an accurate gauge of the reliability or utility of the behaviour they exhibit.
477 A sophisticated assessment of a model's credibility must involve calibration of self-declared
478 knowledge and behavioural accuracy of the model. Adults are able to make such calibrations
479 (Tenney, MacCoun, Spellman, & Hastie, 2007; Tenney, Spellman, & MacCoun, 2008) but,
480 whilst four- and five-year-olds are able to make accurate judgements regarding knowledge
481 and accuracy independently, they are unable to discredit models that exhibit inconsistencies
482 between knowledge and accuracy (Tenney, Small, Kondrad, Jaswal, & Spellman, 2011).
483 This, again, supports the notion that children can process single model-based biases but find
484 the calibration of multiple biases challenging. There is perhaps a cognitive cost associated
485 with model-based biases; some model-based biases, such as a bias towards pedagogical cues,
486 may be automatic and dominate in younger children even when more relevant model
487 characteristics, such as proficiency, are available.

488

489 **Summary**

490 We have highlighted some of the cognitive skills required for children to employ
491 model-based biases. Many of these skills develop in the first five years of a child's life and
492 are a vital part of a child's social cognition; for example, monitoring affect and perspective
493 taking. Other cognitive skills enable children to move beyond employing model-based biases,
494 to evaluating these biases. This leads to flexibility in their use by understanding context,
495 assessing specialists and generalists, tracking prior personal experience and calibrating
496 multiple biases. These abilities require other cognitive skills such as language and working
497 memory. Additionally, many of these cognitive skills show a developmental shift and require

498 experience. Development increases flexibility in the use of model-based biases that allows
499 children to move beyond simple biases to evaluating context as well as a model's behaviour.

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Section 3: Future directions

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503 Here, we suggest avenues of investigation of model-based biases beyond our
504 argument of their adaptive value and exploration of their development. Specifically, we focus
505 on the emerging argument that social learning and, potentially, model-based biases are not
506 solely based on individuals acquiring the best environmental information and that model-
507 based biases may not always lead to the most adaptive behaviour. Following this, we
508 highlight the usefulness of a comparative perspective, demonstrating that model-based biases
509 in non-human animals show both convergences and divergences with that of children.

510

511 Understanding the social side of model-based biases

512 This review has deliberately focussed on the adaptive value of model-based biases,
513 arguing that preferentially copying certain models will lead to learning the most adaptive
514 behaviour for one's environment. However, we accept that we have assumed that the
515 behaviours copied are primarily functional (e.g. tool use or culturally appropriate). However,
516 to-be learnt behaviour may also be inherently social, and social interaction is an additional or
517 alternative function of imitation (Grusec, & Abramovitch, 1982; Over & Carpenter, 2012;
518 Užgiris, 1981). Therefore, an interesting future direction would be to focus on the interplay
519 between social and functional motivations to copy within the context of model-based biases.
520 For example, as seen in the previous section, children's model-based biases change if the to-
521 be-copied behaviour becomes more social (e.g. play) than functional (Zmyj et al., 2011).
522 Investigating model-based biases in the context of how the content of the modelled behaviour

523 affects the use of model-based biases would shed more light on whether the same biases are
524 employed differently when the domain of the to-be-copied behaviour varies.

525 Additionally, it would be interesting to explore model-based biases which focus on
526 the social behaviour of models, building upon work showing that how socially engaging a
527 model is can affect whether children copy her or him (Elekes & Kiraly, 2012; Nielsen, 2006;
528 Nielsen, Simcock, & Jenkins, 2008). Nielsen (2006) and Nielsen & Blank (2011) argue that
529 this is due to a social motivation to share an experience or create an affiliation and that
530 certain social, or indeed anti-social behaviours, influence the copying of functional
531 behaviours. Furthermore, witnessing scenarios involving third-person ostracism can increase
532 imitation in children (Over & Carpenter, 2009). This last example, whilst not demonstrating a
533 model-based bias, does suggest that the model-based biases in the previous examples may be
534 a by-product of an emotional reaction to a social situation rather than an evolutionary
535 adaption. Of course, such behaviour might be both an emotional reaction and adaptive, in that
536 pro-social behaviour is thought to be an evolutionary adaption (Dawkins, 1989). Thus
537 children may be biased towards copying models that are pro-social both in order to obtain
538 pro-social traits and because pro-social behaviour offers a degree of prestige.

539

540 **Understanding when model-based biases may not be adaptive**

541 As mentioned in the introduction, social learning is not seen as universally adaptive
542 and there may also be instances whereby a model-based social learning strategy is not
543 inherently adaptive. For example, a bias towards copying a model that is successful in one
544 domain might lead to other, non-adaptive behaviours, also being copied from this model, a
545 phenomenon that is often used in advertising through celebrity endorsements. This
546 "piggybacking" (Mesoudi & O'Brien, 2008, p 23) of non-adaptive behaviour from a
547 particular model could lead to maladaptive behaviour. An example of this is the copying of

548 causally irrelevant actions demonstrated by an adult, but not a child, model (Wood, et al.,
549 2012). The potential side effects of model-based biases need to be better understood in order
550 to understand their pervasiveness and development.

551

552 **Comparative research**

553 It is interesting to see whether model-based biases are unique to humans. A
554 comparative perspective is also useful to developmental research as the presence or absence
555 of particular biases may shed light on what cognitive skills (present or absent in other
556 species) are necessary and/or sufficient for model-based biases to be used. The adaptive
557 nature of model-based biases has been discussed in relation to non-human animals'
558 (henceforth animals) social learning (Laland, 2004) and there has been a surge of activity
559 directed at identifying and understanding the variety of biases that might influence social
560 learning in animals (Kendal, Coolen, van Bergen, & Laland, 2005; Rendell et al., 2011).
561 Work with animals demonstrates some interesting convergences with children. For example,
562 in line with proposition 1, both dogs (Range, Viranyi, & Huber, 2007) and chimpanzees
563 (Buttelmann, Carpenter, Call, & Tomasello, 2007) seem able to assess a model's intentions,
564 and are more likely to copy unusual behaviour when it seems intentional. Both these species
565 are social animals perhaps suggesting a link between social cognition and this bias.

566 In line with proposition 2, that children are biased towards copying the most
567 proficient models, capuchin monkeys prefer to observe more successful models although
568 there was no evidence that this increased their copying of one model over another (Ottoni, de
569 Resende, & Izar, 2005). Kendal et al (submitted) fitted statistical models to chimpanzees'
570 interactions with an extractive foraging advice and found some evidence that chimpanzees
571 copy expert individuals. Investigating this proposition in animals seems like a fruitful avenue.
572 More research has been conducted with animals regarding proposition 3, that children are

573 biased towards models belonging to a group that may have a reputation for being more
574 proficient; stickleback fish copy the feeding location of older, larger fish as opposed to
575 smaller, younger fish (Duffy et al., 2009). Mice are more influenced by the food choices of
576 adult mice over younger mice (Choleris, Guo, Liu, Mainardi, & Valsecchi, 1997) and young
577 female guppies copy the mate choice of older versus younger female guppies (Amlacher &
578 Dugatkin, 2005). Wild chimpanzees show selective attention towards observing models of
579 the same age or older, but not younger, than themselves (Biro et al., 2003), and captive
580 chimpanzees' copying of food retrieval methods is influenced more by older versus younger
581 individuals (Horner, Proctor, Bonnie, Whiten, & de Waal, 2010). The breadth of species that
582 show this bias indicates that it is a relatively cognitively simple model-based bias to process.

583 In line with proposition 4, some animals are biased towards models who are more
584 genetically similar to themselves (rats; Saggerson & Honey, 2006) and more familiar (fish;
585 Swaney, Kendal, Capon, Brown, & Laland, 2001), again suggesting that this may be a salient
586 model-based bias. Finally, with regard to proposition 5, some animals are biased towards
587 individuals with high status; dominant individuals appear to elicit social learning more than
588 subordinates in a wide variety of species (e.g. chimpanzees, Bonnie, Horner, Whiten, & de
589 Waal, 2007, Horner et al., 2010; capuchins, Dindo, Thierry, & Whiten, 2008; hens, Nicol &
590 Pope, 1994, 1999; and seals, Sanvito, Galimberti, & Miller, 2007). However, the degree to
591 which this is analogous to a copying high-status individuals bias in children depends upon the
592 degree to which high-status represents aggressive force (power) or deference (prestige) in
593 human and non-human species. Work with animals also offers some interesting
594 interpretations for these biases. For example in lemurs, dominant individuals were more
595 likely to be copied, as they monopolised resources (Kendal et al., 2010) and thus provided the
596 most demonstrations. In children non-monopolization of resources has been seen (Flynn &
597 Whiten, 2012) yet the bias remained; the dominant children were watched out of choice.

598 Another interesting interpretation from animal research is that increased social
599 learning from a particular model may not always be due to model-based biases, but instead be
600 due to an attentional by-product. Benskin, Mann and Lachlan (2002) and Katz and Lachlan
601 (2003) suggest that female finches copy the feeding location of male rather than female
602 conspecifics because females pay attention to males as potential mates, while females do not
603 need to attend to one another. Conversely, male finches show no feeder preference because
604 male finches pay equal attention to males (as potential rivals) and females (as potential
605 mates). Likewise, male canaries are more innovative and better at personally learning a new
606 feeding behaviour, but behaviours demonstrated by the females are more likely to be copied
607 as the males are aggressive towards male observers (Cadieu, Fruchard, & Cadieu, 2010).
608 Lastly, wild vervet monkeys learn to retrieve more food from an artificial fruit task when the
609 task is modelled successfully by a female rather than a male, possibly because of females'
610 tolerance of observer presence (van de Waal, Renevey, Favre, & Bshary, 2010) or their
611 likelihood, as the philopatric sex, of possessing relevant knowledge.

612 This body of work on animals suggests that model-based biases are not unique to
613 humans. However, what may be unique to humans is the flexibility with which biases are used
614 through children's developing ability to be receptive to pedagogical cues (Call & Tomasello,
615 1999), perspective take (Brosseau-Liard & Birch, 2011), categorise and generalise
616 proficiency (Koenig & Jaswal, 2011), assess context (Zmyj et al., 2011) and calibrate
617 multiple model-based biases (Jaswal & Neely, 2006), not to mention our species'
618 understanding of complex language and higher-order mental state understanding (Jaswal &
619 Malone, 2007). Alternatively, what could be unique to humans is that copying serves a social
620 as well as a functional motivation, as outlined above (Nielsen, 2009). Animals may have the
621 ability to categorise and generalise proficiency, or calibrate multiple model-based biases, and
622 these are avenues that need further investigation.

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Conclusions

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Children are prolific social learners, adopting the language, tool-use, knowledge and beliefs of those around them. We have highlighted that children do not source information indiscriminately, but rather use biases to guide their copying of others' behaviour. What makes children's social learning truly impressive is their ability to implement strategies of model-based biases. These biases are adaptive in that they enable children to source the 'best' trait variant without the cost of assessing every trait variant displayed within the environment. Whilst some biases seem automatic, children need a suite of cognitive skills to use other model-based biases. These cognitive abilities are not all necessary for the occurrence of model-based biases, but they all assist in ensuring model-based biases are effective, because they enhance children's appraisals of models and allow children to flexibly evaluate the context. Model-based biases and some of the accompanying cognitive skills required to learn and maintain these biases are not unique to humans. However, the combination of model-based biases and children's development of species-unique socio-cognitive skills (Dean, Kendal, Schapiro, Thierry, & Laland, 2012; Whiten & Erdal, 2012), such as language and understanding another's mental states, means that children stand alone in their ability to source the right model for them, in the right context, and use this model's behaviour to guide their own behaviour; resulting in a uniquely adaptive form of social learning. Research into model-based biases now needs to go beyond identifying the presence and direction of model-based biases and move towards an understanding of the relationship between specific cognitive skills and the emergence and development of individual biases and the interaction (and potential changeable hierarchies) of different model-based biases.

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