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.

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

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

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

This review uses an evolutionary approach to understand how model characterisitcs bias the likelihood that an observing child copies modelled behaviour. We define copying as a broad behaviour of a child either matching the behaviour of a model or preferentially selecting one model's behaviour (e.g. a novel object is given a different word label by two models and when prompted, the child repeats one of the models' word labels). Copying is an important mechansim in children's social learning. Whilst focusing on instances of copying a model, we acknowledge that children are able to learn behaviour without necessarily reproducing every aspect of a demonstration (Bekkering, Wohlschläger, & Gattis, 2000; Flynn & Whiten, 2008; Williamson, Meltzoff, & Markman, 2008) and that copying a model may serve a function beyond simply learning behaviour (Over & Carpenter, 2011). In Section 1 we argue that model-based biases enable children to gain the most useful information pertaining to their environment; hence a model-based bias may be viewed as an adaptive cognitive tool. Throughout this review, adaptive means that the model-based bias contributes to an individual's survival by providing them with more useful behaviours within their environment, or enables avoidance of unreliable or redundant information, than if such a model-based bias did not exist. In Section 2 we describe the developmental shift in the implementation of model-based biases, demonstrating increasingly flexible implementation. We conclude in Section 3 by discussing future considerations and directions.

Section 1: The adaptive value of model-based biases

In this section we make five propositions regarding the adaptive value of model-based biases. To begin, we examine children's biases towards models whose behaviour indicates their desire to transfer information, namely children's receptiveness to pedagogical cueing. Second, we consider children's ability to evaluate and copy the most proficient individual before moving on to discussing characteristics that identify models as belonging to groups with certain reputations that may guide children's copying. Fourth, we argue that the more similar a model is to a child, the more suitable s/he might be as a model, before finishing by discussing children's biases towards models that are prestigious.

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

Csibra and Gergely (2009) argue that children have an innate predisposition for receptiveness towards people's ostensive signals indicating that the person is trying to communicate relevant information. These cues may include pointing, eye contact, and verbal directions. If a person is actively trying to communicate information then, generally, the person is communicating information about the environment that they believe will assist the observer. Being sensitive to a model's ostensive cues is adaptive because it enables children's attention to be drawn to important aspects of the environment. The sensitivity to ostensive cues is present from infancy, for example fourteen-month-olds search where they see someone point (Behne, Carpenter, & Tomasello, 2005) and copy the unusual action of turning a light on with their head if told by the model "I'm going to blick the light' as opposed to just "Look at this" (Chen & Waxman, 2013). This sensitivity influences which models individuals copy; children copy a model more when s/he stoops to the child's level, leans in, makes eye contact and talks engagingly (Brugger, Lariviere, Mumme, & Bushnell, 2007), gives verbal cues about the importance of actions (Southgate, Chevallier, & Csibra, 2009) or performs actions in a seemingly purposeful, rather than accidental manner (Carpenter, Akhta, & Tomasello, 1998; Gardiner, Greif, & Bjorklund, 2011). Indeed this receptiveness to pedagogical cueing is so strong it can limit exploratory play and discovery (Bonawitz, Shafto, Gweon, Goodman, Spelke, & Schulz, 2011). Thus, children are receptive to pedagogical cueing and are biased towards copying models who attempt to share information about the environment.

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

A model's success in a particular context indicates his or her ability to deal with that environment, therefore a successful model's behaviour is the most adaptive behaviour to adopt. There is evidence that infants are able to discriminate between models who act competently or incompetently (Zmyj, Buttelmann, Carpenter, & Daum, 2010) and seven-year-old children preferentially copy children rated by an experimenter as being competent rather than less competent (Brody & Stoneman, 1985). Likewise, the 'Trust' paradigm (Harris, 2007; Koenig & Harris, 2005a), whereby children are introduced to one reliable model (e.g., labels a ball, "ball") and one unreliable model (e.g., labels a ball, "shoe"), has demonstrated that, from infancy to six-years-old, children consistently copy reliable models over unreliable labellers for novel words (Koenig et al., 2004; Koenig & Harris, 2005b; Vázquez, Delisle, & Saylor, 2012) and artefact use (Birch, Vauthier, & Bloom, 2008; Zmyj et al., 2010). The labelling of artefacts are more likely to be copied from models who self-declare they know what is right (declaring, "this is a spoon") than models who are uncertain ("*I think* this is a fork"; Jaswal & Malone, 2007) and models who are labelled as smart rather than not smart (Lane, Wellman & Gelman, 2012). Thus, children are able to discern the proficient model and are biased towards the information this model provides.

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

Employing model-based biases regarding an individual's proficiency is costly in terms of time and cognitive processing, as it requires an assessment of the behavioural history of a model. Instead, it is more efficient for an individual to be biased towards characteristics of models that are easily identifiable, often indicating an individual's membership to a group. This group may have a different reputation for proficiency from another group leading to model-based biases. For example, a salient characteristic indicating group membership is age. A 'copy older over younger models' strategy seems adaptive because older individuals have had more experience with the environment and, by their continued existence, have made successful choices within the environment. Such age biases exist. Fifteen-month-olds are more likely to copy videotaped target acts when presented by an adult versus a two-year-old child (Seehagen & Herbert, 2011). Younger (one- to two-year-olds) siblings copy the spontaneous social behaviours of their older (three- to five-year-old) siblings far more than the other way around regardless of age gap or sex differences (Abramovitch, Corter, & Pepler, 1980; Pepler, Abramovitch, & Corter, 1981). Three- and four-year-olds preferentially copy information provided by an adult over a child for novel object labelling (Jaswal & Neely, 2006), and object less when a puppet copies an adult, rather than a child model demonstrating alternative actions on a novel game (Rakoczy, Hamann, Warneken, & Tomasello, 2010). Also, seven- and eight-year-olds copy the food choices of older rather than younger children (Brody & Stoneman, 1981). This bias towards copying older individuals is also seen in the reproduction of causally irrelevant actions by children; when models use causally-inefficient tools, adults are more likely to be copied than children (Elekes & Kiraly, 2012), two- and three-year olds do not copy the irrelevant actions demonstrated by a peer to the same extent as when demonstrated by adult models (Flynn, 2008; Horner & Whiten, 2005), and three- and five-year-olds copy relevant actions of both child and adult models but only faithfully reproduce the irrelevant actions of adults (McGuigan, Makinson, & Whiten, 2011; Wood, Kendal, & Flynn, 2012). Potentially, children assume that increased age indicates increased proficiency and use this bias to guide their copying (although see Section 2 for instances where this does not happen).

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

Individual differences result in individualised needs within an environment. These differences can influence children's proclivity to gain information from a model that is most similar to them, an 'observer-specific model-based bias'. This observer-specific bias may happen at a genetic, physiological or cultural level. For example, four- and five-year-olds generally accepted their mother's claims over those of a stranger (Corriveau et al., 2009) indicating that children may select information from those more genetically related to them. Familiarity is a confound to this interpretation, yet familiarity itself can be a marker of in-group membership and infants copy more actions of a familiar, compared to an unfamiliar, model (Learmonth, Lamberth, & Rovee-Collier, 2005). Likewise, three- to five-year-old children, given conflicting artefact labels and functions from a known or unknown teacher, preferentially copy the known teacher (Corriveau & Harris, 2009b). Children also copy the choices of familiar models when choosing personal preferences or labelling artefacts (Shutts, Kinzler, McKee, & Spelke, 2009) and in tool use tasks (Buttelmann, Zmyj, Daum & Carpenter, 2012; Seehagen & Herbert, 2011). This preference for copying familiar models is adaptive because the child and the model have definite overlaps in their environment whereas the history of the stranger is unknown and, therefore, the information they provide may not be relevant for the child's particular environment.

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

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

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

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

Teacher ratings of social status and dominance of children correlate with observable characteristics, such as the age of a child (Grusec & Lytton, 1988), his/her size, and the number of wins in agonistic encounters with other children over resources (Pellegrini et al., 2007). Flynn and Whiten (2012) investigated both dominance and prestige in pre-school children's social learning. There was evidence of a status-based model-based observation bias in these children; in a naturalistic, open diffusion setting with a novel puzzle-box, older children were watched more than younger children, popular children were watched more than less popular children, and more dominant children were watched more than less dominant children. This observation bias indicates a potential copying bias of more prestigious individuals. As dominant children did not monopolise the task, it seems they were watched out of choice. Further, children were more likely to watch task manipulations made by peers they stated that they ‘liked’ rather than peers they stated that they did ‘not like’. Likewise, McGuigan (2013) found that the higher the status of the model (the child’s head teacher versus a known researcher) the greater the number of irrelevant actions were copied.

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

Summary

We have outlined five propositions relating to the presence and adaptive value of model-based biases. Indeed, the propositions outlined can be adapted to make testable predictions about model-based biases. For example, in line with Proposition 1 we predict that any model who, through verbal or non verbal means, communicates an intention to teach will be more likely to be copied than a model who provides no cues or non-pedagogical communication. Likewise, we predict that, in line with Proposition 3, groups that have a reputation for being more proficient will be copied more than comparative groups. Whilst this section focussed on age we believe that other groups relating to, for example, profession, level of education or expertise, could illicit the same model-based biases.

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

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

This section reflects on some cognitive skills required in two periods of child development, infancy and early childhood, which enable and assist in implementing model-based biases. The cognitive skills described here are relatively high-level and based on empirical papers detailing model-based biases. Therefore, lower-level cognitive processes, such as working memory, categorisation or language development are not discussed, although future work addressing the influence of these processes on model-based biases seems pertinent. Cognitive skills develop throughout infancy and early childhood and this development affects the use of model-based biases. We argue that these developing cognitive skills enable children to flexibly employ model-based biases in response to environmental and behavioural cues. This flexibility is important because it allows children to continually source and copy the 'best' model even when there are complex, subtle and multiple model characteristics.

From Infancy

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

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

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

Context also affects biases toward copying models belonging to a particular group, such as an age group. One- and two-year-olds generally imitate spontaneous behaviour exhibited by adults more than peers, but the context affects this replication, such that imitation of parents is more likely to consist of motor skills (e.g. tool use) whereas affective behaviours are imitated from siblings and peers (Kuczynski, Zahn-Waxler, Radke-Yarrow, 1987). These two types of behaviour (motor skills and affective behaviours) represent different functions, and therefore could elicit different model-based biases. This extends into early childhood; four- to five-year-old children imitate adults more than children and same age peers when an action is novel, but copy a peer over an older child and adult when the action is not novel (Zmyj et al., 2011). In the first context, the function may be to learn a new skill and, therefore, children should be biased towards copying the model who belongs to the more proficient group whereas in the second context, the action is familiar and, therefore, the predominant motivation may be to copy behaviour appropriate for a child, and thus children copy another child. Indeed, when the context is play infants show higher fidelity copying of a three-year-old child versus an adult (Ryalls, Gul, & Ryalls, 2000) and peers over older children and adults (Zmyj, Aschersleben, Prinz, & Daum, 2012), and children also prefer clothes, toys, games and foods endorsed by children over those endorsed by adults (Shutts et al., 2010). Furthermore, in a diffusion chain paradigm, when an adult demonstrated functionally irrelevant actions, in a functionally oriented way, the first child copied these actions but subsequent children parsed out the action of the child model they had witnessed (Flynn, 2008). Conversely, when an adult model demonstrated irrelevant actions in a playful way the behaviour spread; the children copied the child models (Nielsen, Cucchiaro, & Mohomedally, 2012). This implies children assess the context and copy individuals belonging to groups who will be most proficient in that context, so will most aid their interaction with that environment. Alternatively, and as discussed in Section 3, copying may not always be driven by a desire to learn but instead a desire to share a social experience (Užgiris, 1981), or become more integrated with a social group (Over & Carpenter, 2012).

Context also influences perceptions of the relative proficiency of one model (or group) over another model (or group). When three- to five-year-olds, presented with stick figure ‘adult’ or ‘child’ models, were asked who would provide more reliable answers to questions, children selected the adult when the questions were within the adult domain, such as the nutritional value of food, but when the subject area was toys children deferred to the child model (VanderBorght & Jaswal, 2009). An ability to consider the domain of the behaviour alongside the model characteristics is adaptive as it allows for contextual flexibility in behaviour. Moreover, children demonstrate flexibility in their choice, such that when children are informed that a toy is ‘the adult’s favourite toy’ they defer to the adult, rather than a child model, for subsequent information regarding that toy (VanderBorght & Jaswal, 2009). The additional flexibility of understanding that there may be exceptions to a domain appropriate model-based bias is cognitively sophisticated and adaptively biases the child towards the most proficient model in each specific instance.

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

From Early Childhood

Evaluating a model’s testimony. Evaluating model testimony is important for proposition 2 (children are biased toward copying the most proficient models). Here we see an example of a cognitive skill that develops throughout early childhood, influencing the discrimination of particular models. Studies involving model testimony have shown that three-year-olds show mixed discrimination of proficient and less proficient models, with evidence of copying the behaviour of the reliable model (Birch et al., 2008; Corriveau & Harris, 2009a) but also a lack of discrimination of accurate over inaccurate informants (Koenig & Harris, 2005b). However, by four to six years, children consistently copy reliable models over unreliable labellers for copying labels for novel objects (Koenig et al., 2004; Koenig & Harris, 2005b; Vázquez et al., 2012) and artefact use (Birch et al., 2008). Six-year-olds also copy reliable labellers over tangential labellers, who are not inaccurate but fail to answer the question, although four-year-olds fail to make such a distinction (Vázquez et al., 2012). Furthermore, three-year-olds have difficulty discriminating between models when the reliable informant is anything other than 100% accurate, whereas four-year-olds are able to make distinctions between a model who was right 75% of the time versus a model who was right 25% of the time (Pasquini, Corriveau, Koenig, & Harris, 2007). Recently, Lucas, Lewis, Pala, Wong & Berridge (2013) have shown an association between specific cognitive skills and evaluation of a model's testimony; children who demonstrated stronger false belief understanding were more likely to copy the model with the more accurate prior testimony, than children with poorer false belief understanding. Whether it is the development of false beliefs per se or the ability to hold in mind multiple constructs at the same time, irrespective of whether they refer to mental states or not, this study shows a clear developmental shift in the use of model based biases. Furthermore, this study highlights the importance of investigating which specific cognitive skills affect model-based biases.

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

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

Assessing specialists and generalists. Evaluation of model testimony might depend upon the speciality of the model's knowledge and the speciality of the to-be-learnt behaviour. Humans have common shared knowledge; we all know the difference between cats and dogs. But we also have specialist knowledge; doctors have expertise in anatomy while farmers have expertise with crops. It follows that if a model fails to show proficiency in shared general knowledge the perception of his/her proficiency should be more negatively affected than if the same model fails to show proficiency in an area of specialist knowledge. Young children are able to make this important distinction, as three- and four-year-olds do not copy a model who specialised in labelling dog species over a neutral model for novel artefact labelling, but a model who wrongly labelled dogs as cats was not chosen over a neutral model (Koenig & Jaswal, 2011). This skill improves with development (Koenig & Jaswal, 2011); whilst four-year-olds do not generalise beyond word knowledge having witnessed a reliable word labeller, five-year-old children generalise that the reliable word labeller will also excel in broader facts (Brosseau-Liard & Birch, 2010). This assessment of specialists and generalists allows children to use more subtle group membership model-based biases rather than more salient distinctions (e.g. age) whilst ensuring that they realise the potential limitations of this group membership.

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

A child's reliance on her personal information is affected by the interplay between the efficacy of her own behaviour and the efficacy of the model's actions, such that children with a difficult prior experience are more likely to imitate an adult's precise means of achieving something, compared to children with an easy prior experience (Williamson et al., 2008). When the model's tool choice conflicts with the child's knowledge of the optimum tool for task completion, children ignore a model's choice unless the model explicitly states that her method is functionally appropriate or when the model's choice is only slightly less efficient than the child's preference (DiYanni & Kelemen, 2008). A developing confidence in one's personal knowledge within a task thus ensures effective evaluation of a model's behaviour. However, over confidence in one's personal information causes the rejection of potentially useful social information (Jaswal, McKercher, & VanderBorght, 2008); here, children were asked to pick which model gave the right plural or past tense of a novel word. A previously unreliable model's choice was endorsed over a previously reliable model because the unreliable model followed the general grammatical pattern known to the child (add an 's' for plurals and 'ed' for past tense) rather than an irregular change in word. However, what is unclear is whether children accepted the less reliable model's information or whether they just used personal information. Whilst this may lead to a reluctance to accept potentially reliable social information, generally, evaluating the model, relative to ones personal information, generally ensures the critical use of model-based biases.

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

Such calibration also occurs with regard to familiarity and proficiency model-based biases. When three- to five-year-old children were given conflicting artefact labels and functions from a known or unknown teacher they copied the known teacher when no further information was provided (Corriveau & Harris, 2009b). However, when the unfamiliar teacher was more accurate than the familiar teacher at labelling familiar objects, four- and five-year-old children moderated their trust of the models, whilst three-year-olds showed little change in behaviour. Thus, calibration is another cognitive skill that shows changes with development. Perhaps three-year-old children have a bias towards familiar adults but have not developed a proficiency model-based bias. Such an explanation is unlikely as from infancy children seem able to judge proficiency (Zmyj et al., 2010; see proposition 2). Alternatively, three-year-old children may be more influenced by the familiarity bias than a proficiency bias, due to a lack of social interactions with unfamiliar individuals. Lastly, three-year-old children may struggle with such calibration in comparison to older children, perhaps due to a poorer working memory. Such a proposal could be tested by assessing the calibration of older individuals when a cognitive load is put upon their working memory.

There are other instances where children fail to calibrate; when two models *grasp* at opaque cups, three- to four-year-olds choose the cup grasped by the model who saw which cup held the reward (they choose the 'seeing' model), but when both models *point* at the different locations children did not favour the 'seeing' model, indicating that the pointing of the 'unseeing' model was confusing (Palmquist, Burns, & Jaswal, 2012). For children of this age, the model-based biases towards pedagogical cues (pointing) may be stronger than biases towards models that are proficient due to their visual access, the latter of which is more cognitively complex for the child's understanding. Likewise, five-year-old children's imitation of a model is more influenced by the model's group membership (adult versus child) than the model's knowledge state (model stating knowledge or ignorance about task completion) even though children of this age are able to correctly identify knowledge state (Wood et al., 2012). This indicates that a failure to correctly calibrate biases is not due to a lack of ability to implement one of the biases but due to the lack of experience a child has had with multiple biases or the cognitive load required within such calibration.

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

Summary

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

Section 3: Future directions

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

Understanding the social side of model-based biases

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

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

Understanding when model-based biases may not be adaptive

As mentioned in the introduction, social learning is not seen as universally adaptive and there may also be instances whereby a model-based social learning strategy is not inherently adaptive. For example, a bias towards copying a model that is successful in one domain might lead to other, non-adaptive behaviours, also being copied from this model, a phenomenon that is often used in advertising through celebrity endorsements. This "piggybacking" (Mesoudi & O’Brien, 2008, p 23) of non-adaptive behaviour from a particular model could lead to maladaptive behaviour. An example of this is the copying of causally irrelevant actions demonstrated by an adult, but not a child, model (Wood, et al., 2012). The potential side effects of model-based biases need to be better understood in order to understand their pervasiveness and development.

Comparative research

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

In line with proposition 2, that children are biased towards copying the most proficient models, capuchin monkeys prefer to observe more successful models although there was no evidence that this increased their copying of one model over another (Ottoni, de Resende, & Izar, 2005). Kendal et al (submitted) fitted statistical models to chimpanzees' interactions with an extractive foraging advice and found some evidence that chimpanzees copy expert individuals. Investigating this proposition in animals seems like a fruitful avenue. More research has been conducted with animals regarding proposition 3, that children are biased towards models belonging to a group that may have a reputation for being more proficient; stickleback fish copy the feeding location of older, larger fish as opposed to smaller, younger fish (Duffy et al., 2009). Mice are more influenced by the food choices of adult mice over younger mice (Choleris, Guo, Liu, Mainardi, & Valsecchi, 1997) and young female guppies copy the mate choice of older versus younger female guppies (Amlacher & Dugatkin, 2005). Wild chimpanzees show selective attention towards observing models of the same age or older, but not younger, than themselves (Biro et al., 2003), and captive chimpanzees' copying of food retreival methods is influenced more by older versus younger individuals (Horner, Proctor, Bonnie, Whiten, & de Waal, 2010). The bredth of species that show this bias indicates that it is a relatively cognitively simple model-based bias to process.

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

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

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

Conclusions

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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