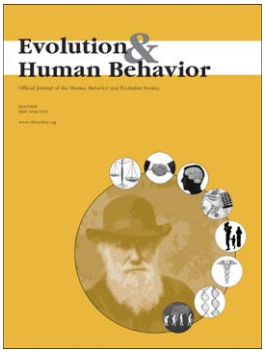

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How does the reliability of a model affect children's choice to learn socially or individually?

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Abstract

The effect of model reliability on children's choices to learn socially versus individually is pertinent to theories addressing cultural evolution and theories of selective trust. Here the effect of a reliable versus unreliable model on children's preferences to learn socially or

individually was examined, as well as their subsequent imitation on a puzzle box task. Experiment One (N=156) found children were more likely to ask to learn socially when presented with a novel task, after witnessing an unreliable rather than a reliable model. Experiment Two (N=40) found children select a new unknown model, over the previously unreliable model, suggesting a preference to learn socially was created, although not specifically from the unreliable model. Experiment Three (N=48) replicated children's learning preference in Experiment One with a new task, and showed children's attention is drawn towards other sources of social information (another adult model) when viewing an unreliable model, and also found a reliable model caused more fidelity of imitation. Together these results suggest that model unreliability causes greater social learning requests and attention to other, even novel, models when they are available. These findings evidence human children's strong propensity to learn socially compared with non-human animals; and suggest there is a more complicated relationship between learning preference, model reliability and selective trust than has been captured in previous research.

Keywords: social learning; model-based biases; selective trust; social learning strategy; cultural evolution

How does the reliability of a model affect children's choice to learn socially or individually?

1. Introduction

Using social information, that is information generated by other individuals' behaviour, can be advantageous in a wide range of situations (Galef & Giraldeau, 2001).

However, the uncritical use of social information is evolutionarily no more adaptive than individual learning (Giraldeau, Valone, & Templeton, 2002; Rogers, 1988), and it has been hypothesised that rules governing selective use of social information may be required to ensure an evolutionary advantage (social learning strategies, SLS, Laland, 2004). Adaptive use of social information is acute for children, who in becoming successful members of their society, must adopt the distinctive beliefs, practices and language of their group (Tomasello, 1999; Vygotsky, 1978). In acquiring this cultural knowledge, children face the problem of determining on which sources of information to rely (Harris, 2007). Selective social learning research has uncovered the importance of: (i) copying based on the frequency of the occurrence of behaviour, (ii) the content of the information, (iii) the state of the learner, and (iv) the characteristics of the demonstrator (Rendell et al., 2011). Here we investigate the latter in children, known as 'model-based biases' in the SLS and cultural evolution literature (Wood, Kendal, & Flynn, 2013); which overlaps, in part, with the 'selective trust in informants' literature (Harris & Corriveau, 2011; Harris, 2007). Both frameworks investigate how a model's attributes affect social learning choices; yet, where selective trust research has primarily compared children's choice between two models, SLS research has had a greater focus on examining how model attributes affect the choice to learn socially versus individually (asocially). With the exception of Flynn, Turner and Giraldeau (2016), the causes and consequences of children's social versus individual learning preferences have not been directly examined. The current research fulfils two main aims: (i) to investigate the role of model reliability on the preference to learn socially versus individually in young children ('learning preference'), and (ii) to shed light on how to interpret the majority of previous selective trust research, which has measured children's selective trust by a comparison choice of the reliability of two models.

Koenig, Clément and Harris (2004) introduced the 'trust' paradigm, which investigates children's preferences for models based on their attributes, particularly reliability. In the trust paradigm procedure, children are typically introduced to two models, one who labels familiar objects accurately, displaying reliability, and one who is inaccurate, displaying unreliability. Both models then give different novel names for unfamiliar objects; with the name which children adopt being a measure of which informant they trust. In this forced choice, young children consistently adopt the labels of reliable over unreliable models (Harris et al., 2013; Koenig & Harris, 2005; Koenig et al., 2004). Children also trust previously reliable models over unreliable models in the tool-use domain (Birch, Vauthier, & Bloom, 2008), and in learning normative rules (Rakoczy, Warneken, & Tomasello, 2009).

Significantly, no study of model reliability has given children the choice to learn a task individually rather than from an informant. Instead, the focus has been on how the properties of different models affect a child's choice of whom to copy and how this operates in different domains. However, it may be the case that children would rather explore a task themselves than learn from certain models. Individual learning has been widely studied in the cultural evolution and animal behaviour literature, as it poses an adaptive alternative method to learn about the world when social information is not fruitful (Giraldeau et al., 2002). Flynn and colleagues (2016) began the study of learning preference in children, by measuring the proportion of children selecting to learn socially versus individually, and how this choice affected task performance. Children were asked if they wanted to attempt to extract a reward from novel puzzle-box apparatus, either by watching a model demonstrate the solution first or attempt the task themselves, learning individually. Children's choice was noted, but they were then in fact randomly allocated to receive a social demonstration or not, allowing the connection between learning preference and performance to be examined over early development. For three- and five-year-olds a substantial proportion wished to learn socially

and performed well when doing so. Interestingly, by five years there was an increased understanding of when attempting a task individually would be effective, with children who selected to learn individually performing better at the task.

Understanding children's learning preference in the light of model reliability extends our understanding of cultural learning and transmission. For instance, Flynn and colleagues (2016)'s findings of a small proportion of individual learners and a general proclivity to learn socially, reflects children's roles in cultural transmission as primarily social learners primed to take adult instruction. The first aim of the current study was to examine how this apparent disposition changes when model reliability changes. It is known that model attributes do affect children's social learning (Wood et al., 2013), and are of importance in cultural transmission in general (Rendell et al., 2011). It might be that children adhere to the model argued to apply to many non-human animals, in which unreliable social information results in a greater propensity to use individual information (Giraldeau et al., 2002). Alternatively, children might follow findings such as those produced by Templeton (1998), in which a preference to observe an unreliable model was found on the basis that observing a lack of success can be more informative than a success (although see Horner & Whiten, 2007).

The current experiment not only contributes to our understanding of the interplay between children's individual and social learning, but also sheds light on the interpretation of the results from experiments using the trust paradigm, by assessing a baseline of propensity to copy reliable or unreliable models. An intuitive hypothesis from the selective trust literature would be that a reliable model would cause a greater proportion of social learning, whereas an unreliable model would promote individual learning. However, previous studies manipulating model reliability across separate conditions, rather than in a forced choice, indicate we may find other results. Koenig and Echols (2003) found infants direct greater attention to models who incorrectly label objects, than those who label objects correctly.

Similarly, Krogh-Jespersen and Echols (2012) found that toddlers were equally likely to learn novel labels from reliable and unreliable speakers. In contrast, Koenig and Woodward (2010) found toddlers learnt novel words less robustly from unreliable rather than reliable informants. Vanderbilt, Heyman and Liu (2014) directly tested the effect of three- and four-year-olds' trust in a unreliable, neutral or reliable model when they were presented in a forced choice versus across separate conditions. They measured children's assessment of the quality of these sources, replicating previous findings of a preference for neutral and reliable models in a forced choice, over an unreliable model. However, the selective trust effect did not extend to situations in which the models were presented separately; in these cases, children used the information from a previously unreliable model in the same proportion as a reliable model and rated them similarly in terms of their value as sources of information. Together these findings point to something more complicated occurring than trusting more reliable informants (and, potentially, distrusting unreliable informants), especially when there is not a direct comparison of informants. It may be that reliable versus unreliable models are quite distinct in the effect they have on children's behaviour; a fact not captured well by forced choice designs. For the second aim of this experiment, contextualising the findings of previous selective trust in informants research, we suggest three competing hypotheses: (i) children will prefer to learn socially from reliable models and individually when presented with unreliable models (Koenig et al., 2004; Koenig & Woodward, 2010), (ii) children will show no difference in learning preference based on model reliability (Krogh-Jespersen & Echols, 2012; Vanderbilt et al, 2014), or (iii) more social learning requests will be produced when presented with an unreliable rather than when presented with a reliable model. For instance, there is increased attention to unreliable models and this may be reflected in increased requests to observe them (Koenig & Echols, 2003), perhaps because they provide more information (Templeton, 1998).

In Experiment One children's preferences to learn socially or individually after viewing a reliable or unreliable model were examined along with aspects of task performance, specifically children's fidelity in copying sequences of actions ('imitation fidelity'). Further, our task allowed an examination of the copying of goals or outcomes as well as sequence copying (by whether children copy the goal of the model in a situation where they were incentivised not to by the possibility of acquiring a larger reward). We also examined the effect of model reliability on task success. The role of a model's reliability on an observer's subsequent behaviour has also received research attention, with evidence showing that a reliable model increases the fidelity and success of subsequent performance (e.g., Zmyj, Buttelmann, Carpenter, & Daum, 2010). The logic of the relationship between model reliability and proclivity to imitate is the same as for novel naming (outlined above): a model's actions and goals are a forms of information, and the degree to which children adhere to this information represents their level of trust (for a review see Wood, Kendal, & Flynn, 2013). However, a disjunction between children's requests for information and action/goal copying is also of theoretical value. For instance, asking for further information carries less risk than engaging in action, therefore children may have a lower threshold for unreliability in the former than the latter.

Experiment One tested three- and five-year-olds, as in Flynn and colleagues (2016). In Experiment Two, children were presented with the opportunity to learn from a model who had previously been established as either reliable or unreliable, or from a new model. This allowed us to elucidate the nature of any social preference; specifically, whether it was a general social preference, thus including new models, or was specific to the model who had previously had their reliability established. Experiment Three extended the research to a new task and examined the attention of children during the stimuli presentation.

2. Experiment One

2.1. Method

2.1.1. Participants

Seventy-eight three-year-olds (39 girls; *M* = 41.99 months, *SD* = 3.02 months) and 78 five-year-olds (37 girls; *M* = 66.20 months, *SD* = 3.22 months) from schools in the North East of England participated. The majority of children were White British, Asian being the second most represented ethnic group. Informed consent was provided by the children's parents, and school's staff. All children verbally consented to participate when asked if they wished to take part. Ethical approval was given by the School of Education's Ethics Committee at Durham University.

2.1.2. Design

A 2 (model reliability: reliable or unreliable) by 2 (learning preference: social or individual) between-subjects quasi-experimental design was employed, over two age groups (three- and five-year-olds); with learning preference also being a measured variable. Control conditions with each age group were conducted, in which children were simply presented with the task, a puzzle box, with no demonstration. This design allowed us to examine: (i) whether children choose to learn socially or individually in relation to the model's reliability, and (ii) how this affected their copying behaviour and success at the task.

2.1.3. Materials

2.1.3.1. Apparatus. A novel apparatus, the 'Duobox' (see Figure 1), was presented to the children. The Duobox is constructed with two side-by-side compartments which were

identical except for the colour of the back wall (blue versus red). All other walls were transparent, so a reward contained inside each compartment could be seen easily. The rewards were a single sticker versus 12 stickers (the size of the large reward was easily distinguishable and appeared appealing when looking into the apparatus), which were counterbalanced across compartments over trials. The same three defences were present on each door at the front of each compartment: (i) a 'lock' that needed to be pulled to the right, (ii) a 'hook' that needed to be pulled to the right, and (iii) a horizontal 'latch' that needed to be twisted to a vertical position, along with an irrelevant action, (iv) a 'bolt' on the top of each compartment could also be removed. The three defences (i, ii and iii) had to be removed to allow a door at the front of the compartment to be opened, and the reward retrieved.

[Insert Figure 1 about here]

2.1.3.2. Reliability stimulus. To manipulate model reliability a stimulus video was created replicating a procedure that has been shown to produce a robust effect for up to a week later (Corriveau & Harris, 2009). The video showed the same model either incorrectly (unreliable model condition), or correctly (reliable model condition) naming four common objects. In the unreliable model condition, the model identified a spoon as a duck, a bottle as an apple, a brush as a plate, and a doll as a cup. Further, the stimulus video showed the model indicating either the usual (reliable model) or casually-impractical (unreliable model) functions for two tools (Birch et al., 2007; Seston Schillaci & Kelemen, 2013). In the unreliable condition, the model stated a potato masher was for drinking, and a sponge was for writing; instead of mashing or washing, respectively, as stated by the reliable model. As a manipulation check, children were asked to identify the above objects and object functions. Ninety-seven percent of five-year-olds and 98% three-year-olds correctly identified three or

more of the four objects; with 95% of both age groups, correctly identifying at least one of the two object functions.

Social learning stimulus. A second video showed the same model opening the Duobox. The model first removed the bolt on the top of the apparatus, and then demonstrated how to remove the three defences on the apparatus (left to right on the apparatus: lock, hook, latch), one after the other. The order in which the defences were removed was held constant, and the model always removed the lower quantity reward (the side, red or blue, was counterbalanced). Images from the stimuli and of the testing spaces are presented in the Supplementary Material.

2.1.4. Procedure

Testing took place in a quiet room away from other children within the child's school. The testing began by showing the child the reliable or unreliable model video. Then the apparatus was revealed to the child, s/he was told it was their job to retrieve something from inside, and asked "Do you want to have a go at getting it out yourself first or do you want to watch the person who you just saw, have a go at getting it out first?" Thus, children had the choice to either learn individually or socially. The child's preference was met, and so either s/he attempted to receive the reward, or were presented with the video of the model retrieving the reward, and then attempted the task.

Learning preference was coded dichotomously depending on the child's request to learn socially (score of 1) or individually (score of -1). Copying of action sequence, imitation fidelity, was coded dichotomously: copying the exact action sequence scored 1, versus performing a different sequence scored -1. Preliminary analyses showed that irrelevant action copying overwhelmingly took place as part of sequence copying and produced the same pattern of results for our questions of interest; the dichotomous measure of overall 'imitation

fidelity', was therefore employed as it was the most explanatory measure of sequence copying for this apparatus (for separate analyses of irrelevant action copying see Supplementary Material). As the non-modelled side had a larger reward, our design also allowed us to examine the effect of reward size on children's goal copying, attempting to retrieve the small reward (copying goal), scored 1, and attempting to retrieve the large reward (not copying goal) scored -1. Children also received a dichotomous score for their task success, measured as successful retrieval of a reward from the Duobox (scoring 1), versus task failure, an inability to retrieve the reward within 5 minutes (scoring -1). A random sample of 20% of the experimental sessions was coded by a second rater who was blind to the aims of the study. A high level of agreement was found (Cohen's κ scores .867–1.000), therefore the original coding was used for analyses.

2.2. Results

2.2.1. Task baseline

When children were only presented with the Duobox, it was found that low levels of both three- and five-year-old children spontaneously used the action sequence performed by the model in the experiment (see Table 1). A large proportion of five-year-olds attempted to attain the larger reward. However, three-year-olds' attempts to retrieve the large reward did not differ from chance. Also, the task appeared not to be overly challenging for five-year-olds, a large proportion being successful at retrieving the reward. Three-year-olds found it challenging, and their success rate did not differ from chance.

[Insert Table 1 about here]

2.2.2. Main question analyses

The first section presents analyses examining relative learning preference, and task performance behaviour (i.e. imitation fidelity, goal copying, and success), between the reliable and unreliable model conditions, along with age. Then, analyses treating reliable and unreliable models as being distinct stimuli, analysing effects on subsequent learning preference/task performance behaviour are reported (as in, Koenig & Echols, 2003; Vanderbilt et al., 2014).

2.2.3. Learning preference with regard to model reliability

We performed a binary logistic regression with learning preference (social coded 1, individual -1) as the dependent variable and model reliability (unreliable coded 1, reliable -1) and age (five coded 1, three -1) included as predictors, $X^2(2, N = 124) = 7.67$, $p = .022$. We also considered a model including an age by model reliability interaction term, but it was found not to be more explanatory, therefore the previous model was preferred. Significantly more children chose to learn socially in the unreliable model condition (70% social, $M = .02$, $SD = 1.01$) than in the reliable model condition (51% social, $M = .41$, $SD = .92$), $\beta = .42$, $SE = .19$, $p = .029$. There was no significant relationship between five-year-olds (70% social, $M = .39$, $SD = .99$) and three-year-olds in learning preference (55% social, $M = .10$, $SD = 1.00$), $\beta = .32$, $SE = .19$, $p = .098$.

After seeing an unreliable model, significantly more five-year-olds chose to learn socially (78%) rather than individually (22%), binomial $t(35) = 3.17$, $p = .001$ (see Figure 2), compared to a null model. However, there was no significant difference for five-year-olds between social (58%) and individual learning preferences (42%) after seeing a reliable model, binomial $t(25) = .59$, $p = .556$. Three-year-olds showed no significant difference between preferences for learning socially (64%) and individually (36%) after seeing the

unreliable model, binomial $t(35) = 1.50$, $p = .135$; nor was there any significant difference in social (58%) and individual (42%) learning preference in the reliable model condition, binomial $t(25) = .59$, $p = .556$.

[Insert Figure 2 about here]

2.2.4. Effect of model reliability on imitation fidelity, goal copying, and success

Analyses of model reliability and age on task performance measures are reported in Tables 1 and 2. There was no significant difference between reliable (41% exact copy, $M = .41$, $SD = .50$) and unreliable model conditions (32% exact copy, $M = 32$, $SD = .47$), in imitation fidelity; however, it was found that five-year-olds (49% exact copy, $M = .49$, $SD = .51$) copied with significantly more fidelity than three-year-olds (18% exact copy, $M = .18$, $SD = .39$). In terms of goal copying, there was no significant difference between reliable (60% model match, $M = .19$, $SD = 1.00$) and unreliable model conditions (67% model match, $M = .20$, $SD = .99$), nor between five- (69% model match, $M = .21$, $SD = .99$) or three-year-olds (64% model match, $M = .18$, $SD = 1.00$). In terms of task success, social learning preference was also entered into the model, there was no significant difference between reliable (87% successful, $M = .74$, $SD = .68$) and unreliable model conditions (82% successful, $M = .63$, $SD = .78$), nor between five- (90% successful, $M = .79$, $SD = .61$) or three-year-olds (71% successful, $M = .41$, $SD = .92$). However, those who chose to learn socially (and thereby did) were significantly more successful (91% successful, $M = .82$, $SD = .58$) than those who chose to learn individually (72% successful, $M = .45$, $SD = .90$).

[Insert Table 2 about here]

Table 1 reports analyses for task performance measures after seeing either a reliable or unreliable model, broken down by age, compared to a null model. Both after witnessing a reliable or unreliable model, three-year-olds used action sequences other than exact copying (low imitation fidelity) at significantly higher proportion than exact copying. Five-year-olds in both model reliability conditions did not differ from a null model in their exact action copying. In both model reliability conditions, and for each age group, goal copying did not differ from a null model. Across model reliability and age group conditions, a significant proportion of children were successful at the task.

2.3. Discussion

Witnessing an unreliable model led to a greater number of social learning requests than witnessing a reliable model. There was no difference based on age for learning preference; however, analyses within model reliability and age group conditions suggests that the social learning preference resulting from an unreliable model may be stronger for five-year-olds than three-year-olds. Similar proportions of social learning preference were seen after observing a reliable model across age groups. However, observing an unreliable, as compared to a reliable model, had no effect on the actions used or success on the task. Five-year-olds copied the demonstrated action sequence more closely than three-year-olds. Yet, there was no age-related difference in task success or goal copying. Asking for and receiving a social learning demonstration made children more successful at the task (as in Flynn et al., 2016).

Regarding learning preference, what was unclear from these findings was whether children in this experiment were disposed to learn specifically from the unreliable model, or whether they simply wanted a social demonstration after having observed an unreliable

model. Within Experiment One's setup, the only social learning option was to learn from the previously witnessed model. Accordingly, on the basis of these findings, it is difficult to determine if children were drawn to learn from the unreliable model because they may provide more information (Templeton, 1998) or because they simply found the model amusing and wanted to see more of them. Or alternatively, if the children were generally inclined to learn socially after witnessing an unreliable model, the only way to fulfil this propensity was to choose the model they had previously seen within this experiment. Therefore, a second experiment was conducted to distinguish between these alternatives. Experiment Two followed the same procedure as Experiment One; however, here the children's choice was to learn either from a model they have previously seen (reliable or unreliable) or a new model. Given that age was not a significant predictor of learning preference, Experiment Two focused on five-year-olds for whom the effect was the strongest.

3. Experiment Two

3.1. Method

3.1.1. Participants

An additional 40 five-year-old children (20 girls) were recruited from the same schools in North East England (M = 64.89, SD = 3.58). Ethical procedures and sample demography were the same as in Experiment One.

3.1.2. Materials

The apparatus and stimuli were identical to those in Experiment One, except that a second set of video stimuli, including a full set of reliability stimuli, for a second model was

employed. The second model wore black, distinguishing them from the original female model, who wore white. The specific model, as well as reliability condition, was counterbalanced across participants (for visualisation of the stimuli see the Supplementary Material). Children saw a separate still image of both models when asked to respond, as outlined below.

3.1.3. Procedure and Design

The procedure used was identical to Experiment One in establishing the reliability of the model, except that one of two sets of stimuli (with the model from Experiment One or the new model) was presented, counterbalanced across conditions. Instead of being asked if they wished to learn socially or individually, children viewed an image of the two models, the model who had been established as reliable or unreliable, and a new (unknown) model. Children were asked to point out this distinction, responding to the question: "Do you want to learn from the girl you watched before, or do you want to watch this new girl?" Children watched their chosen model retrieving the reward from the Duobox, and then they attempted the task. As a manipulation check, after their attempt, children were asked, "Was the model from the video good at naming things or did she get the names wrong?" Eighty-nine percent of children in the reliable condition (binomial $t(18) = 3.21$, $p < .001$) and 79% of children in the unreliable condition (binomial $t(18) = 2.29$, $p = .019$) rightly identified the model's competence or lack of competence. We employed a 2 level (model reliability: reliable or unreliable) between-subjects design, measuring children's preference for the old model they had observed a demonstration of reliability for (scoring -1), or the new model (scoring 1).

3.2. Results

As in Experiment One, we first present analyses comparing model choice then examine effect of conditions separately. Binary logistic regression revealed no difference between reliable (75% new model, M = .10, SD = 1.02) and unreliable (55% new model, M = .50, SD = .89) model reliability conditions (unreliable model coded 1, reliable -1), in predicting children's choice for a new model (coded 1) versus old model (coded -1), $X^2(1, N = 40) = 1.77$, p = .183, β = -.90, SE = .69, p = .190. However, after witnessing an unreliable model, significantly more children chose to learn from a new model than from the (old) unreliable model, binomial $t(19) = 2.01$, p = .041 (see Figure 3). After witnessing a reliable model, there was no significant difference in children's choice to learn from the new model, and the (old) reliable model, binomial $t(19) = .22$, p = .824.

[Insert Figure 3 about here]

3.3. Discussion

Our results reveal that, when children were confronted with a choice of learning from an unreliable model or a new model, children prefer to learn from a new model; with no such differential preference appearing in the reliable model condition. Taken together with Experiment One's results, it appears children wish to learn socially after seeing an unreliable model; yet, when given a choice, this social learning preference is directed to a novel model compared with the previously unreliable model. Several things can be concluded from these results. First, children encode the unreliable source as someone from whom it is less desirable to learn. Second, the desire to learn socially after witnessing an unreliable model is general. That is, third, explanations centred on a legitimate preference to learn from unreliable

models, for instance because they may provide more information (Templeton, 1998), can be ruled out.

Koenig and Echols (2003) found children paid more attention to unreliable than reliable models, providing reasoning about why such a general social learning preference might be found after witnessing unreliable models. Koenig and Echols concluded that an adult labelling familiar objects incorrectly is a surprising event for children, whose expectation is that adults will be an accurate source of communicative information, thus unreliable models draw more attention than a model who is performing reliably. A third experiment was conducted to investigate the role of attention, and by extension expectation/surprise, on children's responses to model reliability within our experimental procedure. Experiment Three measured the portion of children's visual attention towards three targets: (i) the stimuli, (ii) the experimenter (a further adult source of social information), and (iii) distracted/non-directed looking. Not replicating the finding of increased fidelity with a reliable model found in previous research (e.g., Zmyj et al., 2010), a different task with a more overt action sequence was employed; this also allowed us to extend the preference effect found in Experiment One to a further task. Extension to a new task allowed greater generalisability to be gained, ruling-out the possibility that the effect found was specific to the apparatus used.

The measuring of attention within Experiment Three allowed greater inferences to be made about the learning preference produced in response to differentially reliable models. The following are our predictions: If children find the unreliable model's behaviour unexpected, as they assume adult models to be reliable sources of information we may expect greater attention to the unreliable model, as found by Koenig and Echols (2003); however, unlike in that experiment, we also measured the attention to a further potential informant (the experimenter). Accordingly, greater attention may be directed to the experimenter, making

use of social referencing towards a further adult. Alternatively, children might show more distracted looking when presented with the unreliable model, and direct more attention to the reliable model, given the potential utility of each.

4. Experiment Three

4.1. Method

4.1.1. Participants

An additional 48 four- to six-year-old children (24 girls) were recruited from the same schools in North East England (M = 65.52, SD = 6.17). Ethical procedure and sample demography were the same as Experiment One and Two.

4.1.2. Materials

The reliability stimuli were identical to those in Experiment One. To allow a more overt action sequence for measuring imitation fidelity, and to see if the effects found would transfer to a different task, the transparent 'Glass Ceiling Box' used by Horner and Whiten (2005), was used in place of the Duobox. A new social learning stimulus was created, showing the models performing the action sequence outlined in the procedure below. Having been used by Horner and Whiten to examine aspects of action imitation, and processing larger and more conspicuous defences, this apparatus provides a greater chance of observing differences in imitation fidelity, if they exist. Images from the stimulus are available in the Supplementary Material.

4.1.3. Procedure and Design

The procedure used was identical to Experiment One, with the following exceptions. First, cameras were specifically placed to capture where children were looking, as opposed to only focusing on their actions on the task. Second, the experimenter sat to the side of the screen displaying the stimuli, with the position of the experimenter (left or right side), being counter-balanced over conditions. The experimenter looked in his lap, attempting to do this as naturally as possible, and was unresponsive to the child if requests were made. Third, no matter the expressed preference of the child, they all received the social learning stimulus, allowing better sampling of attention during social learning. That is, even when the child asked to learn individually, they were told "hmmm… actually, why don't we see how the woman in the video does it".

Therefore, a 2 level (model reliability: reliable or unreliable) between-subjects design was employed. After the social learning stimulus the actions copied by the participant were also coded (1 if present, 0 if absent, scoring a point for each one copied) to give a continuous imitation fidelity score with a maximum of five: (i) pulling the bolts on the apparatus out using a stick, (ii) putting the stick through the revealed hole in the top of the apparatus, (iii) tapping it three times, (iv) swiping it across the face of the apparatus, (v) sliding the door on the face of the apparatus to the left using the stick. The stick could then be pushed inside the apparatus to retrieve the reward. All children were successful in retrieving the reward. Videos were coded frame-by-frame at 25 frames per second, with the proportion of visual attention (direction of gaze) measured as being directed at the either, (i) the stimulus (monitor), (ii) being distracted (i.e. looking around the room), or (iii) at the experimenter. This visual attention measure was taken for the duration of both the reliability and social learning stimuli, with recording beginning as the model's first reliability response was made of the reliability stimulus, until the end of the stimulus, likewise for the social learning stimulus.

4.2. Results

4.2.1. Preliminary statistics

Learning preference whether social (M = 92.71, SD = 11.45) or individual (M = 95.71, SD = 5.63), did not influence the amount of attention given to the social learning stimulus, between groups $t(45) = 1.05$, $p = .297$. It did not affect the amount of distracted attention (social M = 4.95, SD = 8.72; individual M = 3.82, SD = 4.80), between groups $t(45) = .51$, $p = .610$. Nor did learning preference affect the amount of social attention, (social M = 2.34, SD = 5.34; individual M = .48, SD = 1.81), between groups $t(45) = 1.46$, $p = .151$. Learning preference, whether social (M = 3.07, SD = 1.74) or individual (M = 3.00, SD = 1.48), had no effect on imitation, between groups $t(46) = .15$, $p = .882$. Thus we collapsed these groups in the analysis of model reliability and attention.

4.2.2. Replication of learning preference with regard to model reliability

As in Experiment One, a binary logistic regression found more children in the unreliable model condition (coded 1, 75% new model, M = .10, SD = 1.02) chose to learn socially (coded 1, individually -1) than in the reliable model condition (coded -1, 55% new model, M = .50, SD = .89), $X^2(1, N = 48) = 7.47$, $p = .006$, $\beta = .84$, $SE = .33$, $p = .009$. Further, it was found that there was no significant difference in the reliable model condition in social (40%) and individual (60%) learning preference, binominal $t(23) = .80$, $p = .424$. And again, in the unreliable model condition a significant 78% of children chose to learn socially rather than individually (22%), binominal $t(23) = 2.50$, $p = .011$.

4.2.3. Direction of visual attention

4.2.3.1. Reliability stimulus. When viewing the reliability stimulus there was no significant difference in the proportion of time spent looking at the stimulus with the reliable model (M = 86.65, SD = 12.31) and unreliable model (M = 85.66, SD = 10.58), between groups $t(46) = .30$, $p = .768$. There was also no difference between being presented with the reliable model (M = 10.53, SD = 11.93) and unreliable model (M = 7.64, SD = 8.18), in the proportion of distracted looking, between groups $t(46) = .97$, $p = .336$. However, there was a significant difference in the portion of attention directed at the experimenter, with significantly more attention being directed in the unreliable condition (M = 6.61, SD = 7.12) than in the reliable condition (M = 2.82, SD = 3.47), between groups $t(46) = 2.31$, $p = .027$.

4.2.3.2. Social learning stimulus. During the social learning stimulus there was no significant difference in attention to the social learning stimulus after viewing the reliable (M = 95.16, SD = 6.02) versus the unreliable (M = 92.52, SD = 12.46) model stimulus, between groups $t(46) = .90$, $p = .374$. There was no significant difference in time spent engaged in distracted looking (reliable M = 4.21, SD = 4.96; unreliable M = 4.81, SD = 9.47), between groups $t(46) = .28$, $p = .781$, and there was no difference in time spent looking at the experimenter (reliable M = .64, SD = 1.80; unreliable M = 2.65, SD = 5.95), between groups $t(46) = 1.54$, $p = .137$.

4.2.4. Imitation fidelity by model reliability

In contrast to Experiment One, it was found that those in the reliable model condition (M = 3.72, SD = 1.24) copied with significantly more fidelity than those in the unreliable model condition (M = 2.30, SD = 1.69), between groups $t(46) = 3.33$, $p = .002$.

4.3. Discussion

Experiment Three replicated the effect from Experiment One with regards to learning preference (extending it to a new task), with a majority of children asking to learn socially after witnessing an unreliable model, with there being no difference after a reliable model was presented. There were no differences in the amount of distracted looking or attention to the stimuli when children were presented with either the reliability or social learning stimuli. However, when viewing the reliability stimuli, a greater amount of attention was directed towards the experimenter when the model was unreliable rather than reliable. This is in line with the prediction above, that an unreliable model is a violation of children's expectations about adults as reliable sources of information. Yet, unlike in Koenig and Echols (2003), this was not manifested in greater attention to the unreliable model, but to the experimenter; who the children likely saw as a further source of social information from which they could use to contextualise the unreliable information they witnessed. No effect of attention towards the experimenter was found during the reliability stimulus. Lastly, owing to a more sensitive apparatus for measuring imitation fidelity, we found that the reliable model led to more accurate action copying (as in Zmyj et al., 2010). A potential alternative explanation for the results of Experiment One, that a reliable model caused children to learn individually in greater proportion, appears unlikely given the measured propensity of children to direct more attention to social stimuli in the unreliable model condition.

5. General Discussion

The current study examined young children's choice to learn socially or individually after witnessing differentially reliable models. Children preferred to learn socially after witnessing an unreliable model (Experiment One and Three). When children had a choice, they preferred to learn from a new model rather than the unreliable model they had

previously witnessed (Experiment Two). Therefore, children showed a general preference for social learning after witnessing an unreliable model, rather than a genuine preference to learn from an unreliable model. However, children copied the reliable model with more fidelity, in line with previous research (Experiment Three; Zmyj et al., 2010). Further, an unreliable model caused children to attend more to the experimenter: a potential further adult informant and source of social information (Experiment Three).

It should be noted that in terms of manipulating model reliability, we employed a well-used protocol shown to be effective up to a week later (Corriveau & Harris, 2009). Manipulation checks affirmed children understood the names of the objects in the experiment, and by extension, that the model was departing from these labels. Further, children correctly reported model competence at identifying these objects. Lastly, model reliability had the effect on imitation fidelity that has been found in previous research. Together these facts indicate that children did encode a difference in model reliability between conditions, as produced by accurate versus inaccurate labelling of objects, and object functions.

An adult model acting unreliably is an unexpected event creating an uncertain situation for children. Their response to this uncertainty is to seek further social information, rather than to engage in individual learning. A simple principle of 'when uncertain gain more social information' seems to be in effect; children employing a 'copy when uncertain' strategy (Rendell et al., 2011). This is evidenced by Experiment Two which showed children preferred, when given an option, to seek further information from an additional model rather than the unreliable model, and in Experiment Three with greater attention being directed towards the experimenter in the unreliable model condition. The finding of greater social learning preference after witnessing an unreliable model (Experiment One and Three) can, therefore, be explained by the operation of this principle of unreliability creating a greater

desire for social learning, in a setup where children only had the option to learn socially from the model who they had previously seen. It is interesting to note that in terms of subsequent performance, a reliable model was associated with greater imitation fidelity (Experiment Three). While children did not opt for the option of individual learning in the face of an unreliable model, they were more likely to depart from the methods shown, and in doing so, allowing a greater amount of individual learning, after social learning, to take place.

When social information becomes uncertain research with non-human animals suggests that individuals revert to a strategy of individual learning and exploitation (Giraldeau et al., 2002); indeed, some evidence even shows animals learn more from unreliable models (Templeton, 1998). Alternatively, for humans, selecting to use further models, especially during childhood, would seem to make sense given the central value of culture and social life to humans (Tomasello, 1999). Compared with other animals, children come into the world helpless, but prepared to learn the essential survival skills of their group over an extended development (Nielsen, 2012). Accordingly, compared with other species, children grow-up in ultra-cooperative groups, marked by unusual amounts of alloparenting (Hill et al., 2007), where adults often invest heavily in transmitting this information (Csibra & Gergely, 2011). Individual learning is particularly fraught for human children, while social learning is particularly useful. Indeed, Wood, Kendal and Flynn (2012) showed that five-year-olds prioritise trust in adult models, even over model knowledge state.

Further, obeying the principle of 'learn socially when faced with unreliability', even in the context of Experiment One and Three, in which the only option was to learn from the unreliable model, may not be harmfully costly. Electing to learn socially only added further information at low cost (that of viewing the demonstration). The models in our task still demonstrated how to successfully perform the task, and children could still distill useful information from this demonstration to achieve their goal. It is notable that in the current

study an unreliable model did cause less accurate imitation; recent research by Carr, Kendal, and Flynn (2015), showed even when a model is showing low levels of efficacy on a task, children predominately imitated. Where Carr and colleagues manipulated model unreliability by model failure to retrieve a reward, overimitation research has shown that children imitate models using obviously causally redundant actions. Children will include these redundant actions, even when they are incentivised not to (Lyons et al., 2007). Zmjy and colleagues (2010) found an unreliable model was associated with poorer imitation in an infant sample. Together these results suggest that whether having demonstrated unreliability in (i) naming object names and functions, (ii) attaining the goal of a task, or (iii) being inefficient in using actions to achieve the goal of a task, children will still use these models as sources of social learning; albeit perhaps with a greater propensity to use divergent methods.

These findings add to our understanding of 'selective trust in informants' research. Typically, trust experiments have given children a forced choice between adopting the behaviour presented by a reliable versus an unreliable model. They have generally found children prefer reliable models (Harris et al., 2013; Koenig & Harris, 2005; Koenig et al., 2004). However, experiments measuring choice resulting from models with differing reliability with non-comparison designs (as ours did), have found the preference for reliable models to be less consistent; that is, in designs where children are not given a choice based on a direct comparison between a reliable and unreliable model within the same condition (Krogh-Jespersen & Echols, 2012; Vanderbilt et al., 2014). Our study used a genuinely novel measure, learning preference, where previous studies have generally examined which behaviour is copied, that of a reliable or unreliable model. As to the hypotheses mentioned, the results supported greater social learning, as preferred to individual learning, after seeing an unreliable model. However, we would argue that this does not necessarily imply greater trust, but, as explained, a greater proclivity to want to learn socially given the uncertainty

created by an unreliable model (similar logic given by Koenig & Echols, 2003). When other adults are presented in the experiment, children both request to learn from them, and direct more attention towards them, after being presented with an unreliable model rather than a reliable model. As far as trust (the propensity to rely on an informant), our experiment did find selective trust in reliable informants, as evidenced by the accuracy of imitation. So our findings suggest, first, learning preference does not map neatly onto selective trust, in an intuitive way; instead more social learning requests were made for unreliable models. Second, our findings suggest that further novel and diverging designs are required to continue to fully explore the effect of model reliability on children's learning and development. Using forced choice versus separate condition designs appear to create less consistent findings of trust, and therefore, it would be informative to examine the outcome of an experiment in which learning preference was present in a forced choice design. Second, decoupling 'learning from' and 'acting on the basis of' will likely also be informative; our results suggesting that learning from unreliable models may still occur and be a proclivity of children. However, modulating the use of that information in how one acts is where greater costs occur, and this may be where key differences lie. Lastly, our results suggest including additional informants may importantly change behaviour, third party individuals may be seen as candidates for further information by children; this is also a move towards greater ecological validity, given children develop in a context where multiple adults and be conferred with.

Experiment One suggested that developmental differences between three- and five-years-old were not substantial, however, five-year-olds did show a preference to learn socially after witnessing a previously unreliable model, not found at three years. Further research is needed to properly address the development of learning preference across early years. Any potential difference was not a result of the level of understanding of the

manipulation: both age groups demonstrated that they knew the names and functions of the familiar objects. More likely there is a difference in how three- and five-year-olds interpret a model's incorrect identification of object names and functions. Three-year-olds are still acquiring labels and a model using a novel label may be a weaker cue of unreliability, because the model may be using valid labels the child has not yet encountered. Model reliability did not affect children's goal copying behaviour, however, five-year-olds in the current study copied the demonstrated action sequence more accurately than the three-year-olds; which is in line with research showing a propensity to imitate actions increases with age (Flynn & Smith, 2012; McGuigan, Makinson, & Whiten, 2011). Experiment Three showed that imitation fidelity was detected with a more sensitive apparatus. If children can interpret goals over actions (Gergely, Bekkering, & Kiraly, 2002; Meltzoff, 1988; although see Lyons et al., 2007) children should prefer to match the goals of reliable over unreliable models, in the same way as they do actions. We predict that a different instantiation of goal copying may validate this prediction.

In conclusion, the present study sheds new light on to the effect of a model's reliability on children's social learning. These results suggest that it is not simply the case that children choose to observe reliable models. By giving children the option to learn individually rather than having to copy either a reliable or unreliable in a forced choice, our results suggest an unreliable model increases children's requests for social information and attention, and, when possible, this is requested from an additional model. New and diverging designs must be used to get a full picture of the effects of a model's reliability on children's selective social learning behaviour; future studies are needed to elaborate how to interpret children's learning preference. Further, we considered how children's expectations of adults as reliable sources of information may affect information seeking and subsequent behaviours, in the light of the evidenced pictured of the social and cultural environment in which children

develop. For children, much more than non-human animals, social information is a crucial avenue to learn about the world, a propensity to use social information occurs even in the face of unreliable models; yet, our findings are suggestive of mechanisms which influence differential utilisation of information attained from unreliable models.

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Figures and Tables

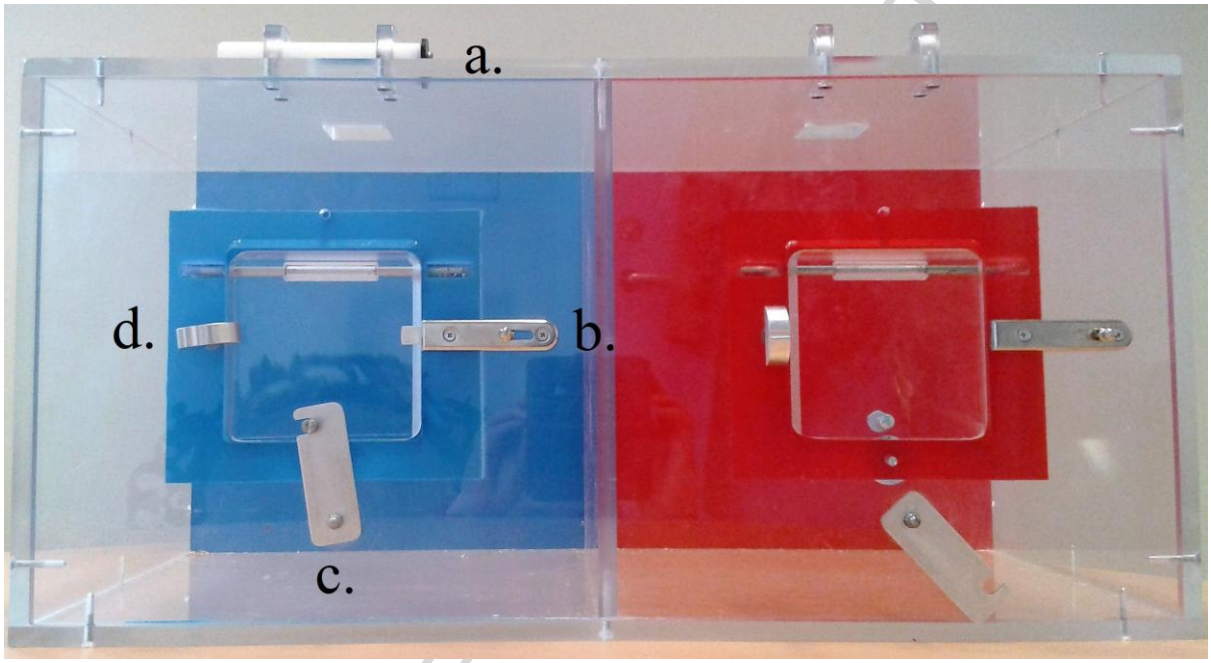

Figure 1. Duobox: left-side shows box in assembled state, right-side shows box with defences removed. (a) 'bolt', (b) 'lock', (c) 'hook', (d) 'latch'.

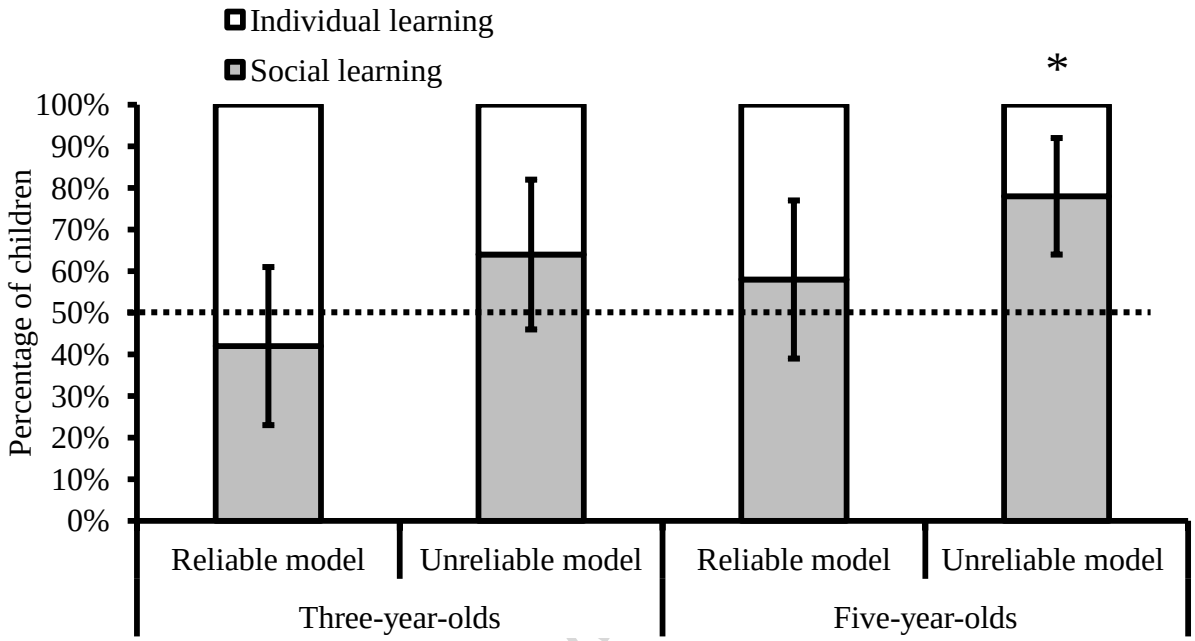

Figure 2. Experiment One: Percentage of children selecting a preference for learning socially versus individually, by age group and model reliability (error bars show ± 95% CI).

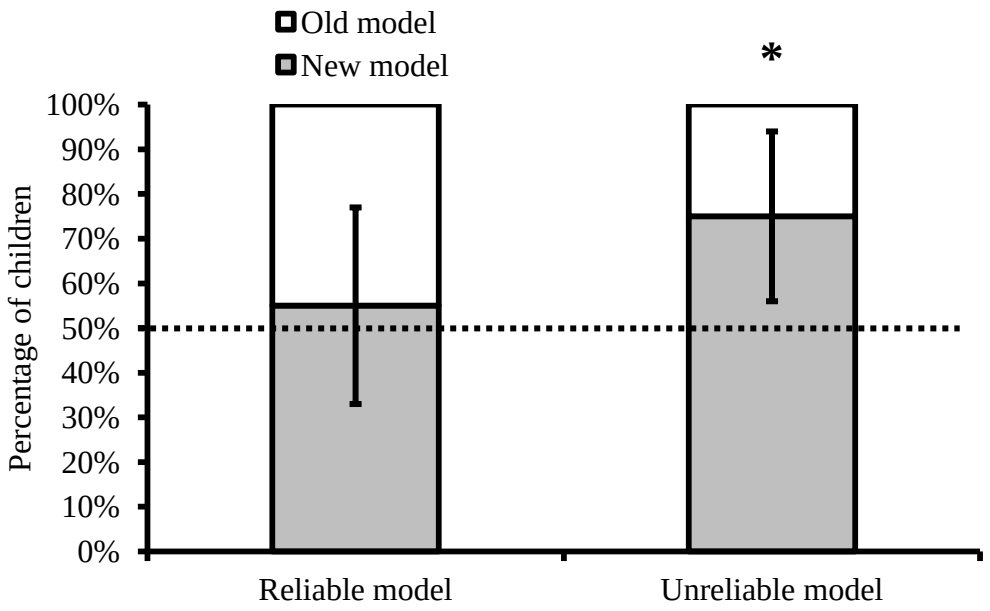

Figure 3. Experiment Two: Percentage of children choosing a new model versus the model they had previously seen (old model) being either reliable or unreliable (error bars show ± 95% CI).

Table 1.

Task performance variables after seeing a reliable or unreliable model, or a no model control, for both five- and three-year-olds.

		Imitation fidelity			Goal copying			Task success		
	n	Exact copy	Other	*p*	Match model	Large reward	*p*	Successful	Unsuccessful	*p*
Five-year-olds										
Control	16	12%	88%	.004*	19%	81%	.021*	88%	12%	.004*
Reliable	15	60%	40%	.606	60%	40%	.607	100%	0%	
Unreliable	28	43%	57%	.606	61%	39%	.345	93%	7%	.001*
Three-year-olds										
Control	16	6%	94%	.001*	31%	69%	.210	44%	56%	.804
Reliable	12	17%	83%	.043*	58%	42%	.773	83%	17%	.043*
Unreliable	22	18%	82%	.006*	67%	33%	.523	86%	14%	.001*

Binominal t-test. *$p < .05$

Table 2.

Experiment One: Comparing model reliability and age on task performance variables.

	Full model			Predictors		
	X^2	df	*p*	*β*	*SE*	*p*
Imitation fidelity	9.17	2	.010*			
Model reliability				-.22	.26	.411
Age				.76	.27	.006*
Goal copying	.25	2	.987			
Model reliability				.02	.24	.950
Age				.03	.23	.884
Task success	4.57	2	.102			
Model reliability				-.37	.28	.184
Age				.43	.27	.116
Learn. Pref.				.70	.27	.009*

Note. $N = 124$. *$p < .05$ Codings for model reliability (unreliable 1, reliable -1), age (five 1, three -1), other variable codings as per section 2.1.4.