The interaction of social and perceivable causal factors in shaping 'over-imitation'

Emily Burdett, Nicola McGuigan, Rachel Harrison and Andrew Whiten

Original citation & hyperlink:
Burdett, E. R., McGuigan, N., Harrison, R., & Whiten, A. (2018). The interaction of social and perceivable causal factors in shaping 'over-imitation'. *Cognitive Development*, *47*, 8-18.
https://dx.doi.org/10.1016/j.cogdev.2018.02.001

ISSN 0885-2014

Publisher: Elsevier

The interaction of social and perceivable causal factors in shaping 'over-imitation'

Emily R. R. Burdett[1,2,3], Nicola McGuigan[4], Rachel Harrison[1, 5], and *Andrew Whiten[1]

[1]Centre for Social Learning and Cognitive Evolution, School of Psychology and Neuroscience, University of St Andrews, South Street, St Andrews, UK KY16 9JP

[2]Brain, Belief, and Behaviour Lab; Centre for Advances in Behavioural Science, Priory Street, Coventry, UK CV1 5FB

[3]Institute of Cognitive and Evolutionary Anthropology, University of Oxford, Oxford, UK OX2 6PN

[4]School of Life Sciences, Heriot-Watt University, Edinburgh, Scotland, UK EH14 4AS

[5]School of Psychology, University of Birmingham, Hills Building, Edgbaston Park Rd., Birmingham, UK B15 2TT

*Corresponding author: aw2@st-andrews.ac.uk

Email addresses: ac5944@coventry.ac.uk (E. R. R. Burdett), N.McGuigan@hw.ac.uk (N. McGuigan), R.Harrison.1@bham.ac.uk (R. Harrison), aw2@st-andrews.ac.uk (A. Whiten)

Author Note: Emily R. R. Burdett and Rachel Harrison conducted this research while at the University of St Andrews. ERRB is now at the Centre for Advances in Behavioural Science, Coventry University and the Institute of Cognitive and Evolutionary Anthropology, University of Oxford, and RH is now at School of Psychology, University of Birmingham.

Abstract

Over-imitation has become a well-documented phenomenon. However there is evidence that both social and visible, physically causal factors can influence the occurrence of over-imitation in children. Here we explore the interplay between these two factors, manipulating both task opacity and social information. Four- to 7-year-old children were given either a causally opaque or transparent box, before which they experienced either (1) a condition where they witnessed a taught, knowledgeable person demonstrate an inefficient method and an untaught model demonstrate a more efficient method; or (2) a baseline condition where they witnessed efficient and inefficient methods performed by two untaught models. Results showed that the level of imitation increased with greater task opacity and when children received social information about knowledgeability consequent on teaching, but only for 6- to 7-year-olds. The findings show that children are selectively attuned to both causal and social factors when learning new cultural knowledge.

Keywords: over-imitation, selective learning, cultural learning, social learning

Highlights:

- Most over-imitation studies employ transparent artefacts yet opacity typifies real world objects
- Over-imitation was greater when children learned about an opaque rather than transparent artefact
- Over-imitation was greater for a model seen to be taught a skill than a naïve model
- These effects combined to elicit over-imitation despite seeing a more efficient model
- All such effects were evident in children aged 6-7 years but not in 4-5-year-olds

The interaction of social and perceivable causal factors in shaping 'over-imitation'

1.1 Introduction

Compared to any other species, humans have an enormous propensity to acquire cultural knowledge (Henrich, 2015; Pagel, 2013). This ability is commonly attributed, at least in part, to an early-developing tendency for high fidelity imitation of the behaviors, skills, and actions of others (Dean, Kendal, Schapiro, Thierry, & Laland, 2012; Schillinger, Mesoudi, & Lycett, 2015; Tennie, Call, & Tomasello, 2009; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). The disposition to copy others has been found to extend in some contexts to children and adults imitating apparently indiscriminately, extending to the copying of even visibly irrelevant or causally superfluous actions (Horner & Whiten, 2005; McGuigan, Whiten, Flynn, & Horner, 2007). It has been suggested that this phenomenon, dubbed "over-imitation" (Lyons, Young, & Keil, 2007) can, in normal daily life, facilitate the spread of cultural knowledge, particularly when skills pertain to tasks that are causally opaque or too difficult for a naive learner to learn on his or her own (Lyons, Damrosch, Lin, Macris, & Keil, 2011; Lyons et al., 2007; Nielsen, Mushin, Tomaselli, & Whiten, 2014), or to behaviors that are associated with rituals or other normative conventions (Herrmann, Legare, Harris, & Whitehouse, 2013; Kapitány & Nielsen, 2015, 2017; Keupp, Behne, & Rakoczy, 2013; Keupp, Behne, Zachow, Kasbohm, & Rakoczy, 2015; Legare, Wen, Herrmann, & Whitehouse, 2015; Watson-Jones, Legare, Whitehouse, & Clegg, 2014; Wilks, Kapitány, & Nielsen, 2016). However, a number of other studies have shown that children and adults are not necessarily indiscriminate imitators; in some contexts they may be selective instead (see for example, Gergely, Bekkering, & Kiraly, 2002; Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013; Nielsen, 2006). Identifying the potentially interacting factors that modulate over-imitation is accordingly important to understanding how children learn new skills and cultural knowledge from others. In this spirit the present study examines the limits and selectivity of children's motivational tendency to copy others, exploring a potential interplay between social and causal factors that may interact in underpinning over-imitation.

In many over-imitation experiments children and adults watch a model perform several actions, some causally relevant and some visibly causally irrelevant. In an initial study, Horner and Whiten (2005) showed children either an opaque or transparent puzzle box and performed a series of causally irrelevant and relevant actions on it before extracting a reward from the box. Regardless of whether the puzzle box was opaque or transparent (so in the latter, causal irrelevance appeared highly visible), children copied the irrelevant actions. What Lyons and colleagues later called "over-imitation", became identified as a pervasive tendency to imitate a series of actions even in the face of visual information that these actions have no causal relevance to the task solution (Horner &

Whiten, 2005; Lyons et al., 2007). Later research has therefore concentrated much on the transparent versions of such tasks, showing that children may continue to copy irrelevant actions even under time constraints (Lyons et al., 2011; Lyons et al., 2007), even when they are given the opportunity of prior experience with how the task works (Nielsen & Tomaselli, 2010), and even when they have been schooled that irrelevant actions are 'silly and unnecessary' (Lyons et al., 2011; Lyons et al., 2007). Such effects have further been documented after children's personal exploration of tasks, despite an irrelevant action occurring after retrieving an award (Wood, Kendal, & Flynn, 2013a), with children who live in quite different cultures (Berl & Hewlett, 2015; Nielsen, Mushin, et al., 2014; Nielsen & Tomaselli, 2010), and despite the absence of any social interaction or audience (Whiten et al., 2016).

A large part of this literature has thus focused on investigating the motivation to over-imitate in the kinds of transparent conditions that first revealed the phenomenon so starkly (Berl & Hewlett, 2015; Brugger, Lariviere, Mumme, & Bushnell, 2007; Carr, Kendal, & Flynn, 2015; Chudek, Baron, & Birch, 2016; Flynn, 2008; Flynn & Smith, 2012; Freier, Cooper, & Mareschal, 2015; Frick, Clément, & Gruber, 2017; Hoehl, Zettersten, Schleihauf, Grätz, & Pauen, 2014; Horner & Whiten, 2005; Kenward, 2012; Kenward, Karlsson, & Persson, 2011; Keupp, Bancken, Schillmöller, Rakoczy, & Behne, 2016; Keupp et al., 2015; Lucas et al., 2017; Lyons et al., 2011; Lyons et al., 2007; Marsh, Pearson, Ropar, & Hamilton, 2013; Marsh, Ropar, & Hamilton, 2014; McGuigan, 2012, 2013; McGuigan & Burgess, 2017; McGuigan, Gladstone, & Cook, 2012; McGuigan, Makinson, & Whiten, 2011; McGuigan & Whiten, 2009; Moraru, Gomez, & McGuigan, 2016; Nielsen, 2013; Ronfard, Was, & Harris, 2016; Schleihauf, Graetz, Pauen, & Hoehl, 2017; Simpson & Riggs, 2011; Taniguchi & Sanefuji, 2017; Vivanti, Hocking, Fanning, & Dissanayake, 2017; Whiten et al., 2016; Wood et al., 2016; Wood, Kendal, & Flynn, 2012; Wood et al., 2013a). Less work has explored what is more likely to be the natural functional context of over-imitation, the everyday world of largely opaque (and moreover causally opaque) objects (Buchsbaum, Gopnik, Griffiths, & Shafto, 2011; Clay & Tennie, 2017; Gardiner, 2014; Gruber, Deschenaux, Frick, & Clement, 2017; Herrmann et al., 2013; Marno & Csibra, 2015; McGuigan et al., 2007; Nielsen, Cucchiaro, & Mohamedally, 2012; Nielsen & Hudry, 2010; Nielsen, Moore, & Mohamedally, 2012; Nielsen, Mushin, et al., 2014; Nielsen, Tomaselli, Mushin, & Whiten, 2014; Subiaul, Krajkowski, Price, & Etz, 2015; Watson-Jones et al., 2014).

The world is full of such complex cultural artefacts and tasks that are physically and causally opaque, too difficult for a naïve learner to master on his or her own. One explanation for the prevalence of over-imitation in experimental, transparent contexts in our species is that humans developed this tendency as an adaptive strategy to acquire complex technological skills in contexts

of causal opacity, by copying the methods shown by experienced others as closely as possible (Lyons et al., 2011; Lyons et al., 2007; Nielsen, Mushin, et al., 2014; Whiten et al., 2009). From this perspective over-imitation can result from a pragmatic "rule of thumb" to imitate in a "copy-all, refine later" functional strategy (Horner & Whiten, 2005). However, more research is required to understand the motivations and flexibility behind imitating in the kinds of opaque conditions so common in the real world. Accordingly we suggest that the context of social learning in relation to opaque as well as transparent objects now merits more attention, and further research.

Based on prior work in transparent conditions where the irrelevancy of actions is visibly apparent, we know that over-imitation can be limited or modulated by several factors. For example, a dimunition of over-imitation can occur based on either social or causal cues. When children are presented with causal information via one model who demonstrates a more efficient method and another model who demonstrates an inefficient one (McGuigan & Robertson, 2015; Nielsen & Blank, 2011; Schleihauf et al., 2017), or when there is visual confirmation that the actions are superfluous (Gardiner, 2014), they are less likely to over-imitate, instead tending to adopt the relatively efficient method. Additional research shows that children are sensitive to the relevance of the communicative intent of others, and over-imitation may decrease when children receive a salient social cue from a model that only the casually relevant elements of the demonstration need to be copied (Brugger et al., 2007; Buchsbaum et al., 2011; Gergely et al., 2002; Nielsen, 2006; Southgate, Chevallier, & Csibra, 2009; Vredenburgh, Kushnir, & Casasola, 2015).

Other social factors have been shown to encourage over-imitation. More specifically, studies demonstrate that children are more likely to imitate irrelevant actions when they perceive ostensive or pedagogical cues that the demonstrator is going to communicate relevant information (Gergely & Csibra, 2005) and that this is the way an action "ought to be done" (Bonawitz et al., 2011; Herrmann et al., 2013; Kapitány & Nielsen, 2015, 2017; Kenward et al., 2011; Keupp et al., 2013; Keupp et al., 2015; Watson-Jones et al., 2014). More normative framing (e.g., doing something that "ought to be done") and goal demoted actions (e.g., actions with no known goal) increases children's imitative fidelity compared to instrumental framing (e.g., doing something "to get prizes") and tasks with a clear goal (e.g., retrieving prizes or putting an object in a box) (Clegg & Legare, 2016b; Legare et al., 2015; Nielsen, Kapitány, & Elkins, 2015; Wilks et al., 2016).

Despite this burgeoning literature examining various social and causal factors (see supplementary Table S1 for a listing of 78 experimental studies that explore a variety of physical and causal factors), no previous work has directly tested the potential interplay between task opacity and social and causal factors. Examining this interplay is needed to shed light on the nature and

functions of over-imitation and the kind of flexible decision making that shapes it. Accordingly, in the present study we explored, for what is to our knowledge the first time, the interplay between the physically causal factors and the social factors that underpin over-imitation. In a 2 x 2 design, participants in four conditions watched two (live) adult models, in a counterbalanced sequence, perform either an inefficient method (incorporating causally-unnecessary elements) or an efficient method (lacking the causally-unnecessary element). In each of the four conditions we held the one inefficient model/one efficient model design constant while we manipulated two factors that may be predicted to increase or decrease the likelihood of over-imitation: first, whether children experienced a transparent or opaque puzzle box, and second whether children received social information (in combination with experiencing a transparent or opaque puzzle box) regarding which model was more knowledgeable (see Table 1). For the latter, we designed a social information condition where the 'inefficient' model was taught, in the presence of the participant, to use the inefficient method by another person. This design enabled us to explore whether witnessing the teaching episode would be sufficiently influential to override the greater efficiency of the alternative method modelled by the naïve demonstrator. We tested participants from two different age groups (4- and 5-year-olds and 6- and 7-year-olds), as previous work has shown that over-imitation tends to increase with age (McGuigan & Graham, 2010; McGuigan et al., 2007).

[Table 1 here]

We predicted that increased physical causal opacity would drive the tendency to copy more irrelevant actions, and that this tendency would be further amplified with the addition of social information that indicated that the inefficient model was demonstrating the "correct" approach (i.e., when the inefficient model had received teaching). Because prior work has shown a relative dimunition of copying of irrelevant actions when the task is framed as an instrumental task (Legare et al., 2015) and when one of two models demonstrates a more efficient action, we predicted less copying of irrelevant actions in the transparent baseline condition (McGuigan & Robertson, 2015; Nielsen & Blank, 2011). More specifically, we predicted that the participants in the baseline conditions, who were acting without social information, would tend to omit the causally irrelevant actions, with the greatest degree of omission (and lowest levels of over-imitation across conditions) occurring in the transparent box condition where the irrelevant actions were most obviously redundant (i.e., no physical causal opacity or social information). In the Taught conditions, noting studies showing that pedagogical cues and normative framing increase copying of irrelevant actions (Herrmann et al., 2013; Kapitány & Nielsen, 2015, 2017; Keupp et al., 2013; Keupp et al., 2015; Legare et al., 2015; Watson-Jones et al., 2014; Wilks et al., 2016), we predicted that the presence of

social information would lead to an increase in the level of over-imitation from that witnessed at baseline irrespective of box transparency, with the greatest increase (and highest levels of over-imitation across conditions) occurring in the opaque box condition where the lack of causality of the irrelevant actions was less apparent, potentially leading to greater reliance on the social information provided (i.e., physical causal opacity plus social information). Thus in summary, copying of irrelevant actions was predicted to be lowest in the *Transparent - Baseline* condition but increase across the series: *Transparent - Taught*, *Opaque - Baseline*, and *Opaque - Taught*. Finally, because prior work has shown that older children are more likely to imitate irrelevant actions (McGuigan & Graham, 2010; McGuigan et al., 2007), we predicted that older children would copy more irrelevant actions compared to younger children.

2.1 Method

2.1.1 Participants

Two age groups were recruited for each of four experimental conditions: a 4-to-5-year-old group (*n* = 83, 41 females, 42 males; *mean age* = 59 months, *SD* = 7.09 months, range 48-72 months) and a 6-to-7-year-old group (*n* = 82, 48 females, 34 males; *mean age* = 83 months, *SD* = 6.96 months, range 72 - 106 months). Forty children (20 4-to-5-year-olds and 20 6-to-7-year-olds) were assigned to a *Transparent box - Baseline* condition, 46 children (23 4-to-5-year-olds and 23 6-to-7-year-olds) to a *Transparent - Taught* condition, 39 children (19 4-to-5-year-olds and 20 6-to-7-year-olds) to an *Opaque - Baseline* condition, and 40 children (21 4-to-5-year-olds and 19 6-to-7-year-olds) to an *Opaque - Taught* condition.

2.1.2 Apparatus

We used the same two cube-shaped boxes from the original study of Horner and Whiten (2005, see Fig. 1). These measured 20 cm on each side and were identical in features except that one box was opaque and the other was transparent. Both boxes displayed two 2 cm x 2 cm holes; one in the front of the box and the other on top, each obstructed by different covers. To access the top hole, two bolts had to be slid aside, through guides holding them in place. The hole in the front could be accessed once a small hatch-door was either slid aside or opened as a hinged flap. Only the front hole allowed access to a prize (a small toy attached to a metallic paperclip) which lay in a small opaque tube, initially covered by the door at the front. A plastic stick-tool, 22 cm long with a magnetic tip, was available to be inserted through the front hole to magnetically seize the prize hidden in the tube. If the tool was inserted into the top hole, it could not reach the opaque tube,

instead hitting a partition that divided the box horizontally. Only actions on the front hole were causally relevant for retrieving the prize (figure 1).

[Figure 1 here]

2.1.3 Design

Children in each age group were randomly assigned to one of four conditions in a between participants design. In two *Baseline* conditions (*Transparent* versus *Opaque* boxes), half of the children witnessed an unfamiliar adult model perform both causally relevant and causally *irrelevant* actions (thus overall, an inefficient method), and then a second unfamiliar adult model perform only the causally relevant actions (efficient method: procedural details and experimenter scripts are described further below). Half the children saw the same two models in the opposite order.

The *Taught* conditions were likewise completed with either the opaque or transparent box. The experimenter declared they would teach one of the two models how to open the puzzle box and did so using the inefficient method, with the accompanying audible cues of tapping the stick tool inside the box. All models in all conditions then said, "I think this is how to get the prize out," and in turn performed either the efficient or inefficient method allocated to them, in counterbalanced order.

2.1.4 Procedure

All children were tested individually in a large gazebo in a quiet area of Edinburgh Zoo. Children and their parents were invited to participate and if they agreed, the child was led into the gazebo and seated at a small table across from the experimenter. The experimenter then invited the child to pick out a prize (e.g., a small plastic monkey) that they would like to earn. The experimenter told the child, "Here is the puzzle box. In a little while I'm going to put your prize inside the box. But, the box is very tricky. So, I'm going to see if I can find two people in the zoo and see if they can come help you figure out the box. If you sit here, I'll go see if I can find some helpers. I'll be right back." The box was placed under the table and out of sight before the experimenter left the gazebo. Two confederates of the experimenter were waiting outside the testing area and were brought inside and asked to sit on either side of the child, where they then acted as the two alternative models in the experiment.

After the confederates and child were seated, the experimenter said, "Thank you - all of you - for helping me today. My name is [experimenter's name]. What are your names? Great. Now, [Child's name] gets to try and get a prize out of a box that I have brought in, but I want both of you

[models 1 and 2] to help [child's name] by showing her/him what you would do to try to get the prize out. Before we get started, I want to show you this stick. This stick here has sticky stuff on it that can pick up a prize. See, like this!" The experimenter then showed the child how a magnetized end of a stick could pick up the prize (attached to the metal paper clip).

Following this instruction, children in the pedagogical condition were told, "Now, I'm going to teach [one of the models] how to get the prize out. While I'm doing this, I'm going to put up the curtain so you and [other model] cannot peek. We'll be back in a minute." The experimenter pulled up a poster-board screen that hid the puzzle box so that the child and the other model could not see the puzzle box, but the screen was short enough that the child and other model could see both the taught model and experimenter. We used a screen to cover the puzzle box so that the child could appreciate that one model was being taught, but the child and the other model would have only an obscured view of what the experimenter actually taught the model. We did this so that the child understood that a model was being taught information without seeing the given method. This was important so that when each model demonstrated their method, the child would see each method demonstrated only once from each model. The experimenter taught both the irrelevant and relevant actions to the model by saying, "This is how to get the prize out" and then performed the actions loudly, striking the stick against the platform inside the box, so that the child could hear what was being done. After teaching this model, the experimenter took away the screen. The baseline condition did not have this added pedagogical component.

Both conditions then proceeded in exactly the same way. The experimenter acknowledged both models and said, "Before I put the prize in and before I give this box to [child's name] so she/he can have a go at getting the prize, I wonder if each of you could show [child's name] how you think you get the prize out." Children watched as one model demonstrated the efficient method and the other model demonstrated the inefficient method (in neither case extracting the prize, which was still held by the experimenter). 'Causally relevant' actions were opening the door on the front of the box, inserting the magnetic tipped tool into the box, and thence retrieving the prize. 'Causally irrelevant' actions involved using the stick tool to displace the bolts to reveal the top hole, then inserting the tool and tapping it down on the inner partition three times. The actions focused on the top hole were causally irrelevant but were only visible in the transparent box, where the role of the inner partition could be seen.

Models were not seen to extract the prize, which at this stage was still held by the experimenter, because we did not want children to see that both methods would be successful. After each model's demonstration, the box was reset (bolts put back in and front door closed) by the

experimenter and out of sight of the child. After the demonstrations were complete, the experimenter thanked both models for their help and both models left. At this point the experimenter asked the child to turn around and cover his or her eyes so that the experimenter could put the prize into the puzzle box. The experimenter then said, "Ok, you can turn around now. Now you can try and get the prize out."

Following the actions, the experimenter then asked, "could you tell me why you decided to get the prize out this way?" and pointed to the actions that the child used.

2.1.5 Coding

The experimenter live recorded the number of causally irrelevant actions performed (number of bolt removals and number of taps on the inner partition of the box), the number of causally relevant actions performed (opening the door on the front of the box, and extracting the reward?), and whether the child repeated the efficient or/or inefficient actions. All actions were mutually exclusive and the design of the box was such that live recording of children's responses was unambiguous. This coding was recorded on a check sheet at the time of the child's actions. To check the reliability of such coding, 30 random videos across conditions were chosen to compare to these check sheets. All videos and sheets matched with 100% reliability.

We also coded an "irrelevance index." This index ranged from 0 to 6. Children were awarded one point for each bolt removed (maximum 2) and one point for each tap, up to four. Only 12 children tapped more than three times; these children tapped between 5-8 times and were spread across all four conditions; accordingly we judged that capping scores in this way was the most apt approach. A score of 0 thus indicated that children did not perform any irrelevant action. A score of 5 was given to children who reproduced the irrelevant actions exactly as in the demonstration by the inefficient model (removing two bolts and tapping three times) and a score of 6 was given to children who performed even more (e.g., tapping more than three times).

3.1 Results

All children successfully extracted the reward. We first used binomial tests to establish whether children in each age group were more likely to adopt the method used by either the efficient model or the inefficient model in each of the four conditions. Here we used strict coding where any use of irrelevant actions was coded as that child adopting the inefficient method. The analyses indicated that the older children were significantly more likely to copy the efficient model than the inefficient model in both *Transparent* box conditions (proportion of choosing efficient model in *Baseline* (0.8) and *Taught (0.74)* against a chance score of .5), *p*s < 0.02, see Fig. 2. This pattern was reversed in

the *Opaque-Taught* condition where the older children were now significantly more likely to copy the inefficient model rather than the efficient model (a proportion of 0.74 inefficient against a chance a score of 0.5, $p = 0.03$). In the *Opaque - Baseline* condition, older children's responses were at chance (0.5), $p > 0.05$. In contrast to the pattern of responding witnessed in the older children, the responses of the younger children differed from chance only in the *Transparent - Taught* condition, where the younger children were significantly more likely to copy the efficient model over the inefficient model, in a proportion of 0.69 against a chance score of 0.5, $p = 0.046$.

[Figure 2 here]

We further tested whether children's responses differed significantly across conditions and according to age. As a more sensitive measure, we examined children's responses using an "irrelevance index". This index ranged from 0 to 6, with a score of 0 indicating that children did not perform any irrelevant action to a score of 6 indicating that children performed all of the irrelevant actions.

We ran a between subjects ANOVA to examine whether there was an effect of age group (4-to-5-year-olds or 6-to-7-year-olds) and condition (*Transparent - Baseline*, *Transparent - Taught*, *Opaque - Baseline*, or *Opaque - Taught*) on the participant's irrelevant action score. This analysis revealed that there was a significant main effect of condition, $F(3, 157) = 3.024$, $p = 0.031$, and an interaction between age group and condition, $F(3, 157) = 18.03$, $p = 0.007$, Fig. 3. There was no main effect for age group, $p = 0.20$.

Post-hoc comparisons using Least Significant Differences revealed that there were significant differences in the number of irrelevant actions performed across conditions in only the older group of children (6-7 years). As predicted, the level of imitation differed according to whether the box was *Opaque* or *Transparent*. Across *Baseline* conditions, older children reproduced more irrelevant actions in the *Opaque* box condition, $M = 2.3$, $SD = 0.46$, compared to the *Transparent* box condition, $M = 0.5$, $SD = 0.46$, $p = 0.007$. Level of imitation also increased based on the social information compared to other conditions. Older children also used more irrelevant actions (evidence that they were copying the taught-inefficient model) in the *Opaque - Taught* condition, $M = 3.21$, $SD = .47$, than in the *Transparent - Baseline* condition, $M = 0.5$, $SD = 0.46$, $p = 0.0001$, and the *Transparent - Taught* condition, $M = 1.13$, $SD = 0.43$, $p = 0.002$. However there were no significant differences in older children's responses between *Baseline* versus *Taught* conditions. Specifically, there were no differences in level of imitation in either the *Opaque* box, *Baseline,* $M = 2.30$, $SD = 0.46$, *Taught*, $M =$

3.21, *SD* = 0.48, *p* = 0.25; or the *Transparent* box, *Baseline, M* = 0.5, *SD* = 0.46, *Taught*, *M* = 1.13, *SD* = 0.43, *p* = 0.25.

A further comparison showed one other difference but between age groups. In the *Opaque - Taught* condition, there were significant differences in the adoption of irrelevant actions between age groups, with the older children reproducing significantly more irrelevant actions, *M* = 3.21, *SD* = 2.37, than the younger group, *M* = 1.38, *SD* = 1.98, *p* = 0.006.

[Figure 3 here]

4.1 Discussion

We believe the present study is the most detailed exploration to date of an interplay between children's recognition of social and physically causal factors underpinning and modulating their tendency for over-imitation. We explored factors modulating children's responses through a 2 x 2 experimental design that manipulated both the challenge of the task in terms of its opacity versus transparency, and the type of social information in the form of taught information transmitted to the model. We predicted that both task opacity and social information would influence the rate of over-imitation. In line with this prediction we found that the copying of irrelevant actions increased with the availability of social information (in this case, concerning an observed pedagogic interaction) and with the physical opacity of the task, but only for older children. Results demonstrate that children can be flexible in their decision-making regarding whether to copy irrelevant actions or not. Below we first discuss the relationship of imitation and task opacity and then consider the influence of social information on imitation.

4.1.1 Acquiring skills in a world of opaque and transparent objects

The world is full of complex cultural artefacts and skills that require time and effort for mastery. It has been hypothesized that in order to learn how to use complex artefacts or to acquire related skills, humans developed a tendency to over-imitate as an adaptive strategy (Lyons et al., 2011; Lyons et al., 2007; Nielsen, Mushin, et al., 2014; Whiten et al., 2009). This is because many artefacts in the human world are quite causally opaque, and typically physically opaque too. Copying what experienced others, like adults, do with them is thus a very helpful practice. In this real world context, the label 'over-imitation' is arguably inaccurate; an expression more like 'strong imitation' might be more apt. The phenomenon only really becomes 'over' imitation in the manipulated world of experiments that incorporate unnecessary actions into physically transparent contexts.

Although it may thus make functional sense to copy faithfully in opaque contexts where the perceptual evidence is lacking, the strength of the phenomenon of "over-imitation" in transparent contexts has remained a puzzle. Over-imitation in a transparent context starkly reveals that children may seem to follow an 'imitation imperative' despite the transparency of what they can see indicating that certain acts of the model are causally unnecessary. A suite of studies has shown that children will over-imitate when presented with a transparent artefact in a variety of circumstances including under time-limited pressure (Lyons et al., 2011; Lyons et al., 2007), prior experience (Nielsen & Tomaselli, 2010), when encouraged to recognize that irrelevant actions are "silly" (Lyons et al., 2011; Lyons et al., 2007), when the irrelevant action occurs after retrieving an award (Wood et al., 2013a), and when in a context where there is no direct social interaction with the model (Whiten et al. 2016). This led Lyons et al. (2017) to infer that over-imitation involves 'automatic encoding' of the model's actions as causal.

However, new work has shown that children have some flexibility and can be selective when copying. The above studies were presented with only one model demonstrating an action. When in our experiment we included a second model who omitted the unnecessary action with the transparent box, the modal response in both baseline and taught conditions, and in both age groups, was to copy this model and thus not to display over-imitation (left half of Fig. 2). This suggests that over-imitation is not automatic, insofar as children across this age range are generally quick to recognize, through the more efficient actions of one model and the transparency of what happens in the transparent box, that certain actions are not worth copying, even though they do not see whether the approaches of either model are successful or not. This suggests that although over-imitation can be a robust phenomenon in one-model contexts, it is at the same time fragile in being undermined by contrary information derived from the actions of others. This conclusion is consistent with the results of some other experiments that employed two models that differed in displaying necessary and unnecessary acts (Hoehl et al., 2014; McGuigan & Robertson, 2015; Nielsen & Blank, 2011), or otherwise showed that over-imitation can be flexibly, and arguably rationally, adjusted to contextual variables (Keupp et al., 2015, 2016). Nevertheless, we must note that over-imitation was still displayed in the two-model and transparent artefact conditions; around as many as one third of the children copied what the inefficient model did (33% in the *Transparent - Baseline* and 28% in the *Transparent - Taught* conditions; left half of results in Fig. 2).

The modal tendency not to copy irrelevant actions in the transparent conditions was not replicated in the opaque conditions, at least for the older age group, where the adoption of unnecessary actions was significantly greater in opaque-baseline than transparent-baseline

conditions, and in opaque-taught than transparent-taught conditions (Fig. 3). This effect was strongest in the taught condition where 6- to- 7-year-olds were even prepared to copy the inefficient actions of the model who had been taught, in preference to the more efficient actions shown by the uninformed model, but the trend was also evident in the condition where neither model was taught. The first of these two effects concerns children's appreciation of the significance of third party pedagogy, which is discussed further below, but the second effect suggests that by this age, children recognize that in the conditions of uncertainty created by opaque artefacts (where they cannot directly see what appears causal or not, like in the transparent box), actions by adults may often be worth copying even though (and indeed perhaps because) they are more elaborate and 'inefficient' than the routine displayed by another adult (Figs. 2 and 3).

4.1.2 The influence of social information: third party pedagogy

The strongest tendency to copy irrelevant actions occurred in the opaque box condition with the older children, who showed a significant inclination to copy the more elaborate procedure of the informed model over the more efficient approach of the uninformed model. There was thus effectively a three-way interaction here between age, opacity of task (and presumably thus, uncertainty) and children's perception of pedagogic information transfer to the model who then performed the more elaborate, although in reality, causally unnecessary actions. The past decade of research has seen a growing numbers of studies identifying how children's social learning may be affected by a model's characteristics, epistemic states, and abilities, described as "selective trust" (e.g., Harris, 2012) or "social learning strategies" (Price, Wood, & Whiten, 2017; Wood, Kendal, & Flynn, 2013b). For example particularly in action based tasks, children are more likely to copy a majority than an individual (Haun, Rekers, & Tomasello, 2012; Herrmann et al., 2013; Hu, Buchsbaum, Griffiths, & Xu, 2013), and a competent over an incompetent person (DiYanni, Nini, Rheel, & Livelli, 2012; Scofield, Gilpin, Pierucci, & Morgan, 2013). The present study adds to this body of work by recognizing a stage at which children will also take into account when models have received relevant third-party pedagogic information.

At first sight it may appear paradoxical that on the one hand, the older children were the more sophisticated, in taking into account the combination of pedagogic information transfer and task opacity in their choice of task solution, yet on the other, they performed more over-imitation, leading them to adopt the solution that was least effective because it incorporated causally unnecessary elements. The latter is consistent with earlier studies finding more over-imitation in older and more cognitively sophisticated children (and indeed in adults), not less (McGuigan et al. 2011; Nielsen & Tomasselli, 2010). We submit that in fact there is no paradox here, insofar as the

older children's 'error' arose simply because of the experimental manipulation, in which it was the taught model who performed the irrelevant actions specifically in order to test for over-imitation on an opaque task. In the real world, this will rarely happen; instead, an adult acting on an object or task will normally offer a good model worth copying, because it typically reflects their mature expertise. Indeed as we suggested above, when we focus on such a real world functionality of 'over-imitation' it is not over-imitation, but should perhaps better be described with a term like 'strong' or 'habitual' imitation.

It is perhaps a little surprising that the response seen in the older children was not apparent in the younger ones, given that the literature would expect the latter to have reached a stage where they recognize distinctions between knowledge and ignorance, and even false belief (e.g., Wellman, Cross, & Watson, 2001). It appears the scenario we presented was more challenging. Although young children's imitation is influenced by pedagogic cues directed directly to them (Gergely & Csibra, 2005), they may not understand third-party pedagogy sufficiently well; for example they may not yet understand the value of taught knowledge, like being shown "the right way" to solve a problem (Clegg & Legare, 2016a, 2016b; Legare et al., 2015) possibly because they do not yet have so much experience in formal education. Future research could explore these alternatives.

Our results are based on the behavior of children living the UK. Another question for future research is to examine whether children in other cultural contexts respond differently on this task (Nielsen, Haun, Kartner, & Legare, 2017). Several recent studies have suggested the possibility that children may interpret pedagogical cues differently (Corriveau et al., 2017; Csibra & Gergely, 2009). For example, one explanation for why first generation Asian-American children compared to Caucasian-American children were more likely to use an inefficient tool over an efficient one to "crush a cookie", is because they interpreted the pedagogical cues normatively and the Caucasian-American were less inclined to do so (Corriveau et al., 2017). Even though our task was framed instrumentally and is an instrumental task, children in a different cultural context with different values, may interpret the pedagogical cues (e.g., "This how you get the prize out") as normative. Future work could examine this cross-culturally.

4.1.3 Conclusion

High-fidelity imitation is thought important in acquiring the skills and knowledge base to acquire complex cultural knowledge. Faithful imitation can be particularly useful for learning causally opaque or difficult-to-acquire knowledge (Lyons et al., 2011; Lyons et al., 2007; Nielsen, Mushin, et al., 2014). In this study we explored children's imitation in both causally transparent and opaque

tasks, creating a test of over-imitation that could apply to both of these by incorporating causally unnecessary elements into the demonstrations of a model the child could see was being taught what to do. The results demonstrate that children aged 6- to- 7-years-old become selective social learners who typically opt to preferentially copy a model they have reasons to believe is knowledgeable about what to do, particularly in the context of opaque tasks. Most over-imitation paradigms exploit transparent artefacts to test for the effect, but given that in the real world children experience many physically and causally opaque artefacts, it is important to extend methodologies to incorporate both contexts, as we did here, along with other social factors. Further study of how other factors contribute to the complexity of children's social-learning promises to provide insight into children's interactions with our culturally-rich worlds.

Acknowledgments. We thank Natalia Fedorova, Sahaj Kang, and Vanessa Burgess for their help with data collection. This work was supported by a John Templeton Foundation grant ID 40128 to AW and K Laland.

References

Berl, R. E. W., & Hewlett, B. S. (2015). Cultural variation in the use of overimitation by the Aka and Ngandu of the Congo Basin. *PLoS ONE, 10*(3), e0120180. doi: 10.1371/journal.pone.0120180

Bonawitz, E., Shafto, P., Gweon, H., Goodman, N. D., Spelke, E., & Schulz, L. (2011). The double-edged sword of pedagogy: Instruction limits spontaneous exploration and discovery. *Cognition, 120*(3), 322-330. doi: 10.1016/j.cognition.2010.10.001

Brugger, A., Lariviere, L. A., Mumme, D. L., & Bushnell, E. W. (2007). Doing the right thing: Infants' selection of actions to imitate from observed event sequences. *Child Development, 78*(3), 806-824. doi: 10.1111/j.1467-8624.2007.01034.x

Buchsbaum, D., Gopnik, A., Griffiths, T. L., & Shafto, P. (2011). Children's imitation of causal action sequences is influenced by statistical and pedagogical evidence. *Cognition, 120*(3), 331-340. doi: 10.1016/j.cognition.2010.12.001

Carr, K., Kendal, R. L., & Flynn, E. G. (2015). Imitate or innovate? Children's innovation is influenced by the efficacy of observed behaviour. *Cognition, 142*(0), 322-332. doi: http://dx.doi.org/10.1016/j.cognition.2015.05.005

Chudek, M., Baron, A. S., & Birch, S. (2016). Unselective overimitators: The evolutionary implications of children's indiscriminate copying of successful and prestigious models. *Child Development, 87*(3), 782-794. doi: 10.1111/cdev.12529

Clay, Z., & Tennie, C. (2017). Is overimitation a uniquely human phenomenon? Insights from human children as compared to bonobos. *Child Development*. doi: 10.1111/cdev.12857

Clegg, J. M., & Legare, C. H. (2016a). A cross-cultural comparison of children's imitative flexibility. *Developmental Psychology, 52*(9), 1435-1444. doi: 10.1037/dev0000131

Clegg, J. M., & Legare, C. H. (2016b). Instrumental and conventional interpretations of behavior are associated with distinct outcomes in early childhood. *Child Development, 87*(2), 527-542. doi: 10.1111/cdev.12472

Corriveau, K. H., DiYanni, C. J., Clegg, J. M., Min, G., Chin, J., & Nasrini, J. (2017). Cultural differences in the imitation and transmission of inefficient actions. *Journal of Experimental Child Psychology, 161*, 1-18. doi: 10.1016/j.jecp.2017.03.002

Csibra, G., & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences, 13*(4), 148-153. doi: http://dx.doi.org/10.1016/j.tics.2009.01.005

Dean, L. G., Kendal, R. L., Schapiro, S. J., Thierry, B., & Laland, K. N. (2012). Identification of the social and cognitive processes underlying human cumulative culture. *Science, 335*(6072), 1114-1118. doi: 10.1126/science.1213969

DiYanni, C., Nini, D., Rheel, W., & Livelli, A. (2012). 'I won't trust you if I think you're trying to deceive me': Relations between selective trust, theory of mind, and imitation in early childhood. *Journal of Cognition and Development, 13*(3), 354-371. doi: 10.1080/15248372.2011.590462

Flynn, E. (2008). Investigating children as cultural magnets: do young children transmit redundant information along diffusion chains? *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1509), 3541-3551.

Flynn, E., & Smith, K. (2012). Investigating the mechanisms of cultural acquisition: How pervasive is overimitation in adults? . *Social psychology, 43*(4), 185-195. doi: 10.1027/1864-9335/a000119

Freier, L., Cooper, R. P., & Mareschal, D. (2015). The planning and execution of natural sequential actions in the preschool years. *Cognition, 144*, 58-66. doi: 10.1016/j.cognition.2015.07.005

Frick, A., Clément, F., & Gruber, T. (2017). Evidence for a sex effect during overimitation: boys copy irrelevant modelled actions more than girls across cultures. *Royal Society Open Science, 4*(12). doi: 10.1098/rsos.170367

Gardiner, A. K. (2014). Beyond irrelevant actions: understanding the role of intentionality in children's imitation of relevant actions. *Journal of Experimental Child Psychology, 119*, 54-72. doi: 10.1016/j.jecp.2013.10.008

589 Gergely, G., Bekkering, H., & Kiraly, I. (2002). Developmental psychology: Rational imitation in
590 preverbal infants. *Nature, 415*(6873), 755-755.
591 Gergely, G., & Csibra, G. (2005). The social construction of the cultural mind: Imitative learning as a
592 mechanism of human pedagogy. *Interaction Studies, 6*(3), 463-481. doi: 10.1075/is.6.3.10ger
593 Gruber, T., Deschenaux, A., Frick, A., & Clement, F. (2017). Group membership influences more social
594 identification than social learning or overimitation in children. *Child Development*. doi:
595 10.1111/cdev.12931
596 Harris, P. L. (2012). *Trusting what you're told: How children learn from others*. Cambridge,
597 Massachussetts: Harvard University Press.
598 Haun, D. B. M., Rekers, Y., & Tomasello, M. (2012). Majority-biased transmission in chimpanzees and
599 human children, but not orangutans. *Current Biology, 22*, 727-731.
600 Henrich, J. (2015). *The secret of our success: How culture is driving human evolution, domesticating*
601 *our species, and making us smarter*. Princeton: Princeton University Press.
602 Herrmann, P., Legare, C. H., Harris, P. L., & Whitehouse, H. (2013). Stick to the script: The effect of
603 witnessing multiple actors on children's imitation. *Cognition, 129*, 536-543.
604 Hilbrink, E. E., Sakkalou, E., Ellis-Davies, K., Fowler, N. C., & Gattis, M. (2013). Selective and faithful
605 imitation at 12 and 15 months. *Developmental Science, 16*(6), 828-840. doi:
606 10.1111/desc.12070
607 Hoehl, S., Zettersten, M., Schleihauf, H., Grätz, S., & Pauen, S. (2014). The role of social interaction
608 and pedagogical cues for eliciting and reducing overimitation in preschoolers. *Journal of*
609 *Experimental Child Psychology, 122*(0), 122-133. doi:
610 http://dx.doi.org/10.1016/j.jecp.2013.12.012
611 Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in
612 chimpanzees (Pan troglodytes) and children (Homo sapiens). *Animal Cognition, 8*, 164-181.
613 doi: 10.1007/s10071-004-0239-6
614 Hu, J., Buchsbaum, D., Griffiths, T. L., & Xu, F. (2013). *When does the majority rule? Preschoolers'*
615 *trust in majority informants varies by domain.* Paper presented at the 35th Annual Meeting
616 of the Cognitive Science Society, Berlin, Germany.
617 Kapitány, R., & Nielsen, M. (2015). Adopting the ritual stance: The role of opacity and context in
618 ritual and everyday actions. *Cognition, 145*, 13-29. doi: 10.1016/j.cognition.2015.08.002
619 Kapitány, R., & Nielsen, M. (2017). The ritual stance and the precaution system: the role of goal-
620 demotion and opacity in ritual and everyday actions. *Religion, Brain & Behavior, 7*(1), 27-42.
621 doi: 10.1080/2153599X.2016.1141792
622 Kenward, B. (2012). Over-imitating preschoolers believe unnecessary actions are normative and
623 enforce their performance by a third party. *Journal of Experimental Child Psychology, 112*(2),
624 195-207.
625 Kenward, B., Karlsson, M., & Persson, J. (2011). Over-imitation is better explained by norm learning
626 than by distorted causal learning. *Proceedings of the Royal Society. Biological sciences,*
627 *278*(1709), 1239-1246. doi: 10.1098/rspb.2010.1399
628 Keupp, S., Bancken, C., Schillmöller, J., Rakoczy, H., & Behne, T. (2016). Rational over-imitation:
629 Preschoolers consider material costs and copy causally irrelevant actions selectively.
630 *Cognition, 147*, 85-92. doi: http://dx.doi.org/10.1016/j.cognition.2015.11.007
631 Keupp, S., Behne, T., & Rakoczy, H. (2013). Why do children overimitate? Normativity is crucial.
632 *Journal of Experimental Child Psychology, 116*(2), 392-406.
633 Keupp, S., Behne, T., Zachow, J., Kasbohm, A., & Rakoczy, H. (2015). Over-imitation is not automatic:
634 Context sensitivity in children's overimitation and action interpretation of causally irrelevant
635 actions. *Journal of Experimental Child Psychology, 130*, 163-175. doi:
636 http://dx.doi.org/10.1016/j.jecp.2014.10.005
637 Legare, C. H., Wen, N. J., Herrmann, P., & Whitehouse, H. (2015). Imitative fidelity and the
638 development of cultural learning. *Cognition, 142*, 351-361. doi:
639 10.1016/j.cognition.2015.05.020

Lucas, A. J., Burdett, E. R. R., Burgess, V., McGuigan, N., Wood, L. A., Harris, P. L., & Whiten, A. (2017). Children's selective copying of their mother versus an expert. *Child Development, 88*, 2026-2042. doi: 10.1111/cdev.12711

Lyons, D. E., Damrosch, D. H., Lin, J. K., Macris, D. M., & Keil, F. C. (2011). The scope and limits of overimitation in the transmission of artefact culture. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 366*(1567), 1158-1167.

Lyons, D. E., Young, A. G., & Keil, F. C. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences, 104*(50), 19751-19756. doi: 10.1073/pnas.0704452104

Marno, H., & Csibra, G. (2015). Toddlers favor communicatively presented information over statistical reliability in learning about artifacts. *PLOS ONE, 10*(3), e0122129. doi: 10.1371/journal.pone.0122129

Marsh, L. E., Pearson, A., Ropar, D., & Hamilton, A. (2013). Children with autism do not overimitate. *Current Biology, 23*(7), R266-R268. doi: http://dx.doi.org/10.1016/j.cub.2013.02.036

Marsh, L. E., Ropar, D., & Hamilton, A. F. C. (2014). The social modulation of imitation fidelity in school-age children. *PLOS ONE, 9*(1), e86127. doi: 10.1371/journal.pone.0086127

McGuigan, N. (2012). The role of transmission biases in the cultural diffusion of irrelevant actions. *Journal of Comparative Psychology, 126*(2), 150-160. doi: 10.1037/a0025525

McGuigan, N. (2013). The influence of model status on the tendency of young children to over-imitate. *Journal of Experimental Child Psychology, 116*(4), 962-969. doi: 10.1016/j.jecp.2013.05.004

McGuigan, N., & Burgess, V. (2017). Is the tendency to conform influenced by the age of the majority? *Journal of Experimental Child Psychology, 157*, 49-65. doi: http://dx.doi.org/10.1016/j.jecp.2016.12.007

McGuigan, N., Gladstone, D., & Cook, L. (2012). Is the cultural transmission of irrelevant tool actions in adult humans (Homo Sapiens) best explained as the result of an evolved conformist bias? *PLOS ONE, 7*(12), e50863. doi: 10.1371/journal.pone.0050863

McGuigan, N., & Graham, M. (2010). Cultural transmission of irrelevant tool actions in diffusion chains of 3- and 5-year-old children. *European Journal of Developmental Psychology, 7*(5), 561-577. doi: 10.1080/17405620902858125

McGuigan, N., Makinson, J., & Whiten, A. (2011). From over-imitation to super-copying: Adults imitate causally irrelevant aspects of tool use with higher fidelity than young children. *British Journal of Psychology, 102*(1), 1-18. doi: 10.1348/000712610X493115

McGuigan, N., & Robertson, S. (2015). The influence of peers on the tendency of 3- and 4-year-old children to over-imitate. *Journal of Experimental Child Psychology, 136*(0), 42-54. doi: http://dx.doi.org/10.1016/j.jecp.2015.03.004

McGuigan, N., & Whiten, A. (2009). Emulation and "overemulation" in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds. *Journal of Experimental Child Psychology, 104*(4), 367-381. doi: 10.1016/j.jecp.2009.07.001

McGuigan, N., Whiten, A., Flynn, E., & Horner, V. (2007). Imitation of causally opaque versus causally transparent tool use by 3-and 5-year-old children. *Cognitive Development, 22*, 353-364. doi: 10.1016/j.cogdev.2007.01.001

Moraru, C-A., Gomez, J-C., & McGuigan, N. (2016). Developmental changes in the influence of conventional and instrumental cues on over-imitation in 3- to 6-year-old children. *Journal of Experimental Child Psychology, 145*, 34-47. doi: http://dx.doi.org/10.1016/j.jecp.2015.11.017

Nielsen, M. (2006). Copying actions and copying outcomes: social learning through the second year. *Developmental Psychology, 42*(3), 555-565. doi: 10.1037/0012-1649.42.3.555

Nielsen, M. (2013). Young children's imitative and innovative behaviour on the floating object task. *Infant and Child Development, 22*(1), 44-52. doi: 10.1002/icd.1765

689 Nielsen, M., & Blank, C. (2011). Imitation in young children: when who gets copied is more important
690 than what gets copied. *Developmental Psychology, 47*(4), 1050-1053. doi:
691 10.1037/a0023866
692 Nielsen, M., Cucchiaro, J., & Mohamedally, J. (2012). When the transmission of culture is child's play.
693 *PLoS ONE, 7*(3), e34066. doi: 10.1371/journal.pone.0034066
694 Nielsen, M., Haun, D., Kartner, J., & Legare, C. H. (2017). The persistent sampling bias in
695 developmental psychology: A call to action. *Journal of Experimental Child Psychology, 162*,
696 31-38. doi: 10.1016/j.jecp.2017.04.017
697 Nielsen, M., & Hudry, K. (2010). Over-imitation in children with autism and Down syndrome.
698 *Australian Journal of Psychology, 62*(2), 67-74. doi: 10.1080/00049530902758613
699 Nielsen, M., Kapitány, R., & Elkins, R. (2015). The perpetuation of ritualistic actions as revealed by
700 young children's transmission of normative behavior. *Evolution and Human Behavior, 36*(3),
701 191-198. doi: http://dx.doi.org/10.1016/j.evolhumbehav.2014.11.002
702 Nielsen, M., Moore, C., & Mohamedally, J. (2012). Young children overimitate in third-party
703 contexts. *Journal of Experimental Child Psychology, 112*(1), 73-83. doi:
704 http://dx.doi.org/10.1016/j.jecp.2012.01.001
705 Nielsen, M., Mushin, I., Tomaselli, K., & Whiten, A. (2014). Where culture takes hold: "overimitation"
706 and its flexible deployment in Western, Aboriginal, and Bushmen children. *Child*
707 *Development, 85*(6), 2169-2184. doi: 10.1111/cdev.12265
708 Nielsen, M., Tomaselli, K., Mushin, I., & Whiten, A. (2014). Exploring tool innovation: A comparison
709 of Western and Bushman children. *Journal of Experimental Child Psychology, 126*, 384-394.
710 doi: http://dx.doi.org/10.1016/j.jecp.2014.05.008
711 Nielsen, M., & Tomaselli, Keyan. (2010). Overimitation in Kalahari Bushman children and the origins
712 of human cultural cognition. *Psychological Science*. doi: 10.1177/0956797610368808
713 Pagel, M. (2013). *Wired for culture: The natural history of human cooperation*. London: Penguin
714 Books.
715 Price, E., Wood, L. A., & Whiten, A. (2017). Adaptive cultural transmission biases in children and
716 nonhuman primates. *Infant Behavior and Development, 48*, 45-53. doi:
717 doi.org/10.1016/j.infbeh.2016.11.003
718 Ronfard, S., Was, A. M., & Harris, P. L. . (2016). Children teach what they could not discover. *Journal*
719 *of Experimental Child Psychology, 142*, 107-117.
720 Schillinger, K., Mesoudi, A., & Lycett, S. J. (2015). The impact of imitative versus emulative learning
721 mechanisms on artifactual variation: implications for the evolution of material culture.
722 *Evolution and Human Behavior*. doi: http://dx.doi.org/10.1016/j.evolhumbehav.2015.04.003
723 Schleihauf, H., Graetz, S., Pauen, S., & Hoehl, S. (2017). Contrasting social and cognitive accounts on
724 overimitation: The role of causal transparency and prior experiences. *Child Development*.
725 doi: 10.1111/cdev.12780
726 Scofield, J., Gilpin, A. T., Pierucci, J., & Morgan, R. (2013). Matters of accuracy and conventionality:
727 Prior accuracy guides children's evaluations of others' actions. *Developmental Psychology,*
728 *49*(3), 432-438. doi: 10.1037/a0029888
729 Simpson, A., & Riggs, K. J. (2011). Three- and 4-year-olds encode modeled actions in two ways
730 leading to immediate imitation and delayed emulation. *Developmental Psychology, 47*(3),
731 834-840. doi: 10.1037/a0023270
732 Southgate, V., Chevallier, C., & Csibra, G. (2009). Sensitivity to communicative relevance tells young
733 children what to imitate. *Developmental Science, 12*(6), 1013-1019. doi: 10.1111/j.1467-
734 7687.2009.00861.x
735 Subiaul, F., Krajkowski, E., Price, E., & Etz, A. (2015). Imitation by combination: Preschool age
736 children evidence summative imitation in a novel problem-solving task. *Frontiers in*
737 *Psychology, 6*(1410), 1-14. doi: 10.3389/fpsyg.2015.01410

738 Taniguchi, Y., & Sanefuji, W. (2017). The boundaries of overimitation in preschool children: Effects of
739 target and tool use on imitation of irrelevant actions. *Journal of Experimental Child*
740 *Psychology, 159*, 83-95. doi: 10.1016/j.jecp.2017.01.014
741 Tennie, C., Call, J., & Tomasello, M. (2009). Ratcheting up the ratchet: on the evolution of cumulative
742 culture. *Philos Trans R Soc Lond B Biol Sci, 364*, 2405-2415.
743 Vivanti, G., Hocking, D. R., Fanning, P., & Dissanayake, C. (2017). The social nature of overimitation:
744 Insights from Autism and Williams syndrome. *Cognition, 161*, 10-18. doi:
745 10.1016/j.cognition.2017.01.008
746 Vredenburgh, C., Kushnir, T., & Casasola, M. (2015). Pedagogical cues encourage toddlers'
747 transmission of recently demonstrated functions to unfamiliar adults. *Developmental*
748 *Science, 18*(4), 645-654. doi: 10.1111/desc.12233
749 Watson-Jones, R. E., Legare, C. H., Whitehouse, H., & Clegg, J. M. (2014). Task-specific effects of
750 ostracism on imitative fidelity in early childhood. *Evolution and Human Behavior, 35*(3), 204-
751 210. doi: 10.1016/j.evolhumbehav.2014.01.004
752 Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory of mind development: The
753 truth about false belief. *Child Development, 72*(3), 655-684. doi: 10.1111/1467-8624.00304
754 Whiten, A., Allan, G., Devlin, S., Kseib, N., Raw, N., & McGuigan, N. (2016). Social learning in the real-
755 world: 'Over-Imitation' occurs in both children and adults unaware of participation in an
756 experiment and independently of social interaction. *PLoS One, 11*(7), e0159920. doi:
757 10.1371/journal.pone.0159920
758 Whiten, A., McGuigan, N., Marshall-Pescini, S., & Hopper, L. M. (2009). Emulation, imitation, over-
759 imitation and the scope of culture for child and chimpanzee. *Philosophical Transactions of*
760 *the Royal Society London B Biological Sciences, 364*, 2417-2428.
761 Wilks, M., Kapitány, R., & Nielsen, M. (2016). Preschool children's learning proclivities: When the
762 ritual stance trumps the instrumental stance. *British Journal of Developmental Psychology,*
763 *34*(3), 402-414. doi: 10.1111/bjdp.12139
764 Wood, L. A., Harrison, R. A., Lucas, A. J., McGuigan, N., Burdett, E., & Whiten, A. (2016). "Model age-
765 based" and "copy when uncertain" biases in children's social learning of a novel task. *Journal*
766 *of Experimental Child Psychology, 150*, 272-284. doi: 10.1016/j.jecp.2016.06.005
767 Wood, L. A., Kendal, R. L., & Flynn, E. G. (2012). Context-dependent model-based biases in cultural
768 transmission: children's imitation is affected by model age over model knowledge state.
769 *Evolution and Human Behavior, 33*(4), 387-394. doi:
770 http://dx.doi.org/10.1016/j.evolhumbehav.2011.11.010
771 Wood, L. A., Kendal, R. L., & Flynn, E. G. (2013a). Copy me or copy you? The effect of prior
772 experience on social learning. *Cognition, 127*(2), 203-213. doi:
773 10.1016/j.cognition.2013.01.002
774 Wood, L. A., Kendal, R. L., & Flynn, E. G. (2013b). Whom do children copy? Model-based biases in
775 social learning. *Developmental Review, 33*(4), 387-394. doi: 10.1016/j.dr.2013.08.002

776

777

778

779

780

781

Table 1.

A 2 x 2 design exploring over-imitation according to task opacity and social information

		Social Information	
		Baseline Untaught	Taught
Task Opacity	Transparent	Transparent(Untaught)	Transparent (Taught)
	Opaque	Opaque (Untaught)	Opaque (Taught)

804 **Figure Captions**

805 *Figure 1.* The 'model' demonstrates a series of actions, some of which are causally irrelevant to goal
806 retrieval (removing bolt defence, inserting tool into top hole), and some which are causally relevant
807 to goal retrieval (removing door defence, inserting tool into lower hole). These actions are illustrated
808 above: (a) causally irrelevant moving top bolt; (b) causally irrelevant tool insertion into top hole; (c)
809 causally relevant tool insertion into the front hole.

810

811 *Figure 2*. Number of children who copied the efficient and inefficient models, by age group and
812 condition. * denotes $p < 0.05$; see text for details.

813

814 *Figure 3*. Mean number of irrelevant actions by condition and age group. * denotes $p < 0.05$.

815

816

817

818

819

820

821

822

823

824

825

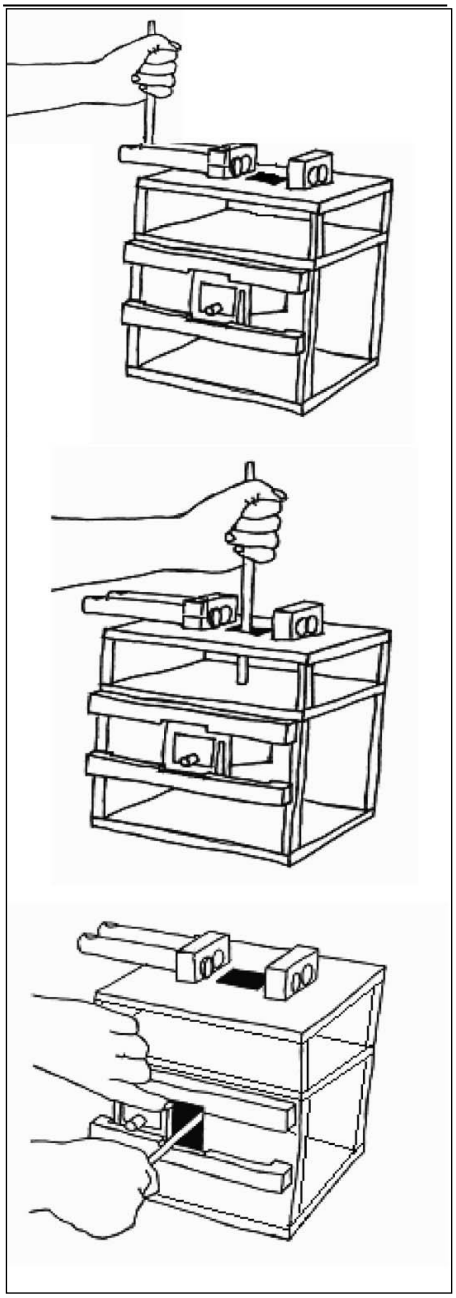
826

827

828

829

a



b

c

830

831

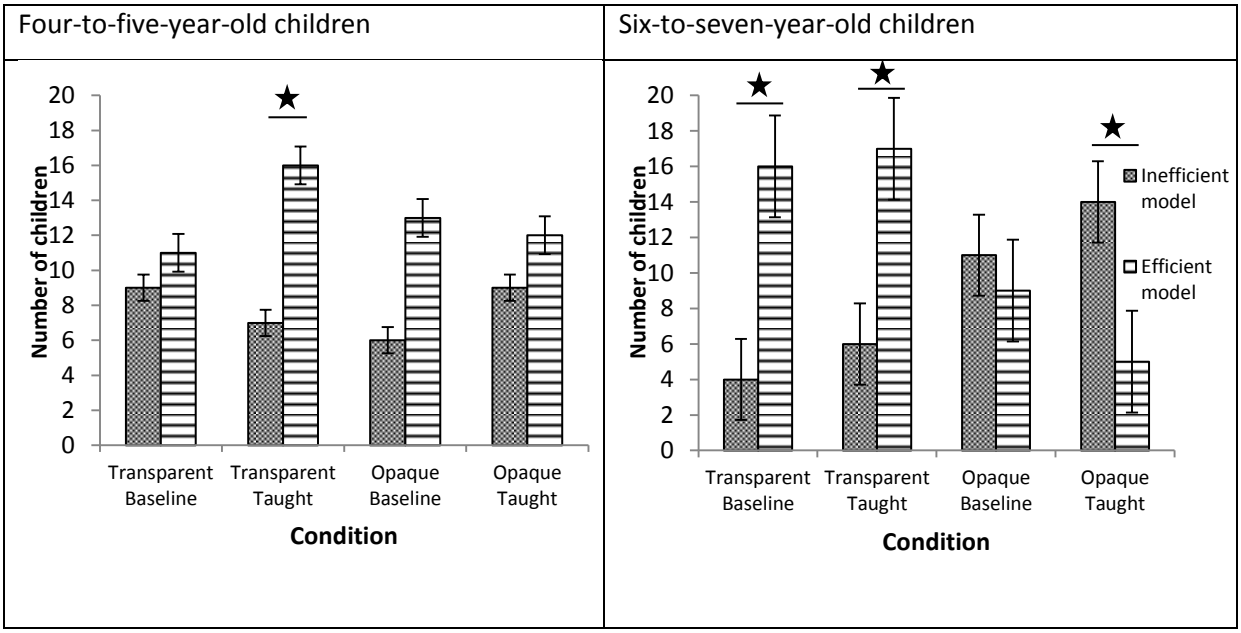
832

833

834

835

836


Four-to-five-year-old children
Six-to-seven-year-old children
Number of children
Transparent Baseline
Transparent Taught
Opaque Baseline
Opaque Taught
Condition
Inefficient model
Efficient model

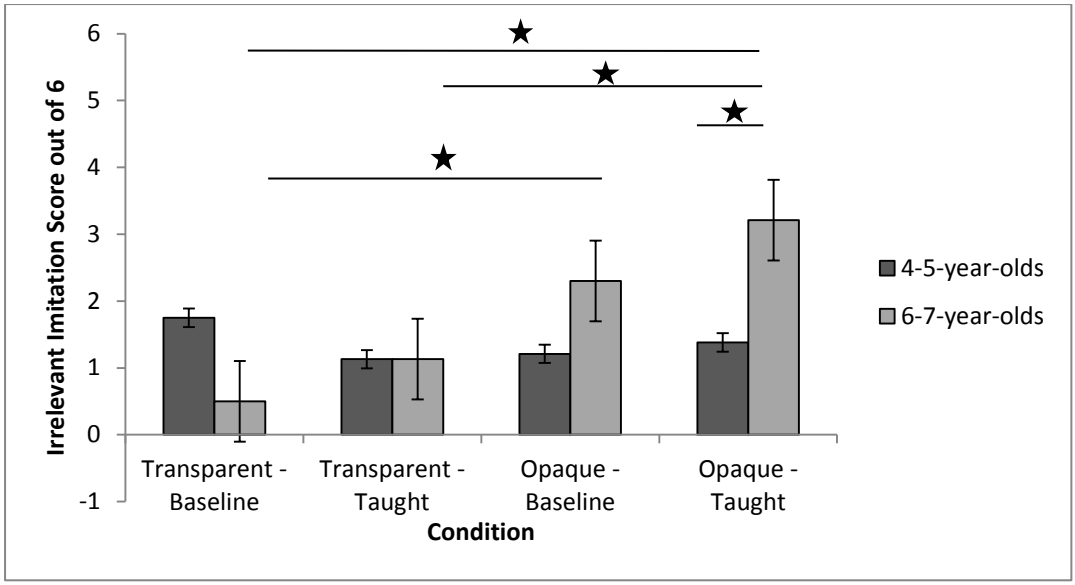

Irrelevant Imitation Score out of 6
6
5
4
3
2
1
0
-1
Transparent - Baseline
Transparent - Taught
Opaque - Baseline
Opaque - Taught
Condition
4-5-year-olds
6-7-year-olds

Table S1. Table of over-imitation and related studies. The table lists studies that (i) include over-imitation in the title or abstract, or in our judgement, otherwise address questions most closely allied to over-imitation; and (ii) include manipulation of objects, whether transparent, opaque, or both, and thus most relevant to our own study. Accordingly we have leaned to being inclusive rather than be over-strict in the coverage of studies here listed, so as to be maximally helpful to those examining or planning to develop research in this area.

Study	Transparent Object/Activity	Irrelevant actions	Opaque Object/Activity	Type of model demonstration
2002				
Gergely, G., Bekkering, H., & Kiraly, I. (2002). Developmental psychology: Rational imitation in preverbal infants. *Nature, 415*(6873), 755-755.	Tough light with hands	Touch light with head	Touch light with forehead	Experimenter demonstrated
2005				
Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (Pan troglodytes) and children (Homo sapiens). Animal Cognition, 8, 164-181. doi: 10.1007/s10071-004-0239-6	Transparent box	Remove bolt, tap into hole on top of box three times	Opaque box	Experimenter demonstrated
2006				
Nielsen, M. (2006). Copying actions and copying outcomes: social learning through the second year. *Developmental Psychology, 42*(3), 555-565. doi: 10.1037/0012-1649.42.3.555		Object directed actions to activate box	Three opaque boxes	Experimenter demonstrated
2007				
Brugger, A., Lariviere, L. A., Mumme, D. L., & Bushnell, E. W. (2007). Doing the right thing: Infants' selection of actions to imitate from observed event sequences. Child Development, 78(3), 806-824. doi: 10.1111/j.1467-8624.2007.01034.x	Box, tube, music box, Toy dog	Undo non-functional latch, patting head with hand, remove barrier, close a trap, take rod out of tube and		Experimenter demonstrated

		place in another		
Lyons, D. E., Young, A. G., & Keil, F. C. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences, 104*(50), 19751-19756. doi: 10.1073/pnas.0704452104	Horner/Whiten box in addition to several other transparent boxes	Remove bolt, tap into hole on top of box three times		Experimenter demonstrated
McGuigan, N., Whiten, A., Flynn, E., & Horner, V. (2007). Imitation of causally opaque versus causally transparent tool use by 3-and 5-year-old children. *Cognitive Development, 22*, 353-364. doi: 10.1016/j.cogdev.2007.01.001	Horner/Whiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/Whiten box	Watched live or video demonstration, or no demonstration
2008				
Flynn, E. (2008). Investigating children as cultural magnets: do young children transmit redundant information along diffusion chains? Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1509), 3541-3551.	Horner/Whiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/Whiten box	Experimenter then child demonstrated
McGuigan, N., & Whiten, A. (2009). Emulation and "overemulation" in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds. Journal of Experimental Child Psychology, 104(4), 367-381. doi: 10.1016/j.jecp.2009.07.001	Horner/Whiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/Whiten box	Experimenter then child demonstrated
2009				
Southgate, V., Chevallier, C., & Csibra, G. (2009). Sensitivity to communicative relevance tells young children what to imitate. *Developmental Science, 12*(6), 1013-1019. doi: 10.1111/j.1467-7687.2009.00861.x	Small cardboard house	Hop, slide, place object in house		Experimenter demonstrated
McGuigan, N., & Whiten, A. (2009).	Horner/W	Use tool	Horner/W	Experimenter

Emulation and "overemulation" in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds. Journal of Experimental Child Psychology, 104(4), 367-381. doi: 10.1016/j.jecp.2009.07.001	hiten box	to remove bolt, tap into hole on top of box three times	hiten box	demonstrated
2010				
McGuigan, N., & Graham, M. (2010). Cultural transmission of irrelevant tool actions in diffusion chains of 3- and 5-year-old children. *European Journal of Developmental Psychology, 7*(5), 561-577. doi: 10.1080/17405620902858125	Horner/Whiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/Whiten box	"Expert" child demonstrator and then, a transmission chain of 8 children
Nielsen, M., & Tomaselli, K. (2010). Overimitation in Kalahari Bushman children and the origins of human cultural cognition. *Psychological Science*. doi: 10.1177/0956797610368808		Use tool to tap, swirl, or wipe box	Three opaque boxes (one from Whiten et al. (1999)).	Experimenter demonstrated
Nielsen, M., & Hudry, K. (2010). Over-imitation in children with autism and Down syndrome. *Australian Journal of Psychology, 62*(2), 67-74. doi: 10.1080/00049530902758613		Object directed actions to activate box	Three opaque boxes	Experimenter demonstrated (Children with ASD and DS)
2011				
Buchsbaum, D., Gopnik, A., Griffiths, T. L., & Shafto, P. (2011). Children's imitation of causal action sequences is influenced by statistical and pedagogical evidence. *Cognition, 120*(3), 331-340. doi: 10.1016/j.cognition.2010.12.001		Knock, stretch, roll toys	Blue ball and stuffed toy with rings/tabs attached	Experimenter demonstrated
Kenward, B., Karlsson, M., & Persson, J. (2011). Over-imitation is better explained by norm learning than by distorted	Rectangular box with two side-by-	Make a paddle rotate by fitting		Experimenter demonstrated

causal learning. *Proceedings of the Royal Society. Biological sciences, 278*(1709), 1239-1246. doi: 10.1098/rspb.2010.1399	side left/right compartments	tool into a bolt on a dial and spinning		
Lyons, D. E., Damrosch, D. H., Lin, J. K., Macris, D. M., & Keil, F. C. (2011). The scope and limits of overimitation in the transmission of artefact culture. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 366*(1567), 1158-1167.	Exp1 & 3: Novel puzzle box based on Horner/Whiten box Exp 2: Novel prize box	Pull wooden dowel Move wooden arm		
McGuigan, N., Makinson, J., & Whiten, A. (2011). From over-imitation to super-copying: Adults imitate causally irrelevant aspects of tool use with higher fidelity than young children. *British Journal of Psychology, 102*(1), 1-18. doi: 10.1348/000712610X493115	Horner/Whiten box	Disconnected actions		Child or adult demonstrator
Nielsen, M., & Blank, C. (2011). Imitation in young children: when who gets copied is more important than what gets copied. *Developmental Psychology, 47*(4), 1050-1053. doi: 10.1037/a0023866		Swipe or tapp outside of the box	2 Wooden apparati	Selective-2 adult models Condition 1: Both adults modeled irrelevant actions Condition 2: one efficient model who stays Condition 3: one efficient model who leaves
Simpson, A., & Riggs, K. J. (2011). Three- and 4-year-olds encode modeled actions in two ways leading to immediate imitation and delayed emulation. Developmental Psychology, 47(3), 834-840. doi: 10.1037/a0023270	Puzzle box	Open top aperture		Experimenter demonstrated
2012				
Flynn, E., & Smith, K. (2012). Investigating the mechanisms of cultural acquisition: How pervasive is overimitation in adults?	Horner/Whiten box	Use tool to remove bolts, tap into hole on top of	Horner/Whiten box	Experimenter demonstrated

Social psychology, 43(4), 185-195. doi: 10.1027/1864-9335/a000119		box once or three times		
Flynn, E., & Whiten, A. (2012). Experimental "microcultures" in young children: identifying biographic, cognitive, and social predictors of information transmission. *Child Development, 83*(3), 911-925. doi: 10.1111/j.1467-8624.2012.01747.x	Horner/Whiten box	Use tool to remove bolts, tap into hole on top of box once or three times	Horner/Whiten box	Adult model/experimenter/ confederate demonstrated depending on exp
Kenward, B. (2012). Over-imitating preschoolers believe unnecessary actions are normative and enforce their performance by a third party. *Journal of Experimental Child Psychology, 112*(2), 195-207.	Push and hook boxes	Push jewels to open space and clean/polish		Experimenter demonstrated
McGuigan, N. (2012). The role of transmission biases in the cultural diffusion of irrelevant actions. *Journal of Comparative Psychology*, 126(2), 150-160. doi: 10.1037/a0025525	Horner/Whiten box	Use tool to remove bolts, tap into hole on top of box once or three times	Horner/Whiten box	Experimenter demonstrated
McGuigan, N., Gladstone, D., & Cook, L. (2012). Is the cultural transmission of irrelevant tool actions in adult humans (Homo Sapiens) best explained as the result of an evolved conformist bias? *PLoS ONE*, 7(12), e50863. doi: 10.1371/journal.pone.0050863	Horner/Whiten box	Use tool to remove bolts, tap into hole on top of box once or three times		One or three adults models demonstrated
Nielsen, M., Moore, C., & Mohamedally, J. (2012). Young children overimitate in third-party contexts. *Journal of Experimental Child Psychology, 112*(1), 73-83. doi: http://dx.doi.org/10.1016/j.jecp.2012.01.001		Use tool to tap, swirl, or wipe box	Three opaque boxes (one from Whiten et al. (1999)).	Third party demonstrations
Nielsen, M., Cucchiaro, J., &		Use tool	2 wooden	Experimenter

Mohamedally, J. (2012). When the Transmission of Culture Is Child's Play. *PLoS ONE, 7*(3), e34066. doi: 10.1371/journal.pone.0034066		to slide	boxes	demonstrated and then child transmission chain (play vs functional way)
Wood, L. A., Kendal, R. L., & Flynn, E. G. (2012). Context-dependent model-based biases in cultural transmission: children's imitation is affected by model age over model knowledge state. *Evolution and Human Behavior, 33*(4), 387-394. doi: http://dx.doi.org/10.1016/j.evolhumbehav.2011.11.010	Horner/Whiten box	Use tool to remove bolt, tap into hole on top of box three times		Adult/child models demonstrated (professing ignorance/knowledge)
2013				
Herrmann, P., Legare, C. H., Harris, P. L., & Whitehouse, H. (2013). Stick to the script: The effect of witnessing multiple actors on children's imitation. *Cognition, 129*, 536-543.		Various actions to move pegs and mallet	Various objects (hammer, peg, board)	Experimenter/s demonstrated
Hilbrink, E. E., Sakkalou, E., Ellis-Davies, K., Fowler, N. C., & Gattis, M. (2013). Selective and faithful imitation at 12 and 15 months. *Developmental Science, 16*(6), 828-840. doi: 10.1111/desc.12070		Remove a strap to open a lid on a box (necessary condition) or remove a strap then opening a lid (unnecessary condition)	Opaque boxes	Experimenter demonstrated
Keupp, S., Behne, T., & Rakoczy, Hannes. (2013). Why do children overimitate? Normativity is crucial. *Journal of Experimental Child Psychology, 116*(2), 392-406.	Plastic boxes	Tapp, brush, turn		Experimenter demonstrated
Kiraly, I., Csibra, G., & Gergely, G. (2013). Beyond rational imitation: learning arbitrary means actions from communicative	Tough light with hands	Touch light with head	Touch light with forehead	Experimenter demonstrated

demonstrations. *Journal of Experimental Child Psychology, 116*(2), 471-486. doi: 10.1016/j.jecp.2012.12.003				
Marsh, L., Pearson, A., Ropar, D., & Hamilton, A. (2013). Children with autism do not overimitate. *Current Biology, 23*(7), R266-R268. doi: http://dx.doi.org/10.1016/j.cub.2013.02.036	Plastic boxes	Tap, slide, stroke, turn		Experimenter demonstrated
McGuigan, N. (2013). The influence of model status on the tendency of young children to over-imitate. *Journal of Experimental Child Psychology, 116*(4), 962-969. doi: 10.1016/j.jecp.2013.05.004	Horner/Whiten box	Disconnected actions		Video demonstrators differing in status (Head teacher, class teachers, unfamiliar adult, familiar experimenter, and unfamiliar adult)
Nielsen, M. (2013). Young Children's Imitative and Innovative Behaviour on the Floating Object Task. *Infant and Child Development, 22*(1), 44-52. doi: 10.1002/icd.1765	Floating peanut task	Small and large cups used to pour water from bottle into peanut tube		Experimenter demonstrated
Nielsen, M., Slaughter, V., & Dissanayake, C. (2013). Object-directed imitation in children with high-functioning autism: testing the social motivation hypothesis. *Autism Research, 6*(1), 23-32. doi: 10.1002/aur.1261		Swipe stick across box in circular motion three times, press mallet onto box three times, use a steel plate like a stamp, wipe spanner three times across	Three opaque boxes	Experimenter demonstrated

		box		
Scofield, J., Gilpin, A. T., Pierucci, J., & Morgan, R. (2013). Matters of accuracy and conventionality: Prior accuracy guides children's evaluations of others' actions. *Developmental Psychology, 49*(3), 432-438. doi: 10.1037/a0029888		Dax the clips, Nedd the ring, bikk the blocks, fepp the stick	Various objects	Two experimenters: One experimenter was unconventionally successful and the other conventionally unsuccessful
Wood, L. A., Kendal, R. L., & Flynn, E. G. (2013a). Copy me or copy you? The effect of prior experience on social learning. *Cognition, 127*(2), 203-213. doi: 10.1016/j.cognition.2013.01.002	Sweep-drawer box	Irrelevant actions after the prize fell		Puppet demonstrated
2014				
Gardiner, A. K. (2014). Beyond irrelevant actions: understanding the role of intentionality in children's imitation of relevant actions. *Journal of Experimental Child Psychology, 119*, 54-72. doi: 10.1016/j.jecp.2013.10.008	Three-step transparent boxes	There were three possible steps to release a prize across three compartments. If the prize was in the second compartment the first step was unnecessary.	Three-step opaque boxes	Experimenter demonstrated (Intentional/accidental)
Hoehl, S., Zettersten, M., Schleihauf, H., Grätz, S., & Pauen, S. (2014). The role of social interaction and pedagogical cues for eliciting and reducing overimitation in preschoolers. *Journal of Experimental Child Psychology, 122*(0), 122-133. doi: http://dx.doi.org/10.1016/j.jecp.2013.12.012	Transparent boxes	Clap, rub disconnected parts		Experimenter demonstrated (non/pedagogical demonstrations)

Marsh, L. E., Ropar, D., & Hamilton, A. F. C. (2014). The social modulation of imitation fidelity in school-age children. *PLOS ONE, 9*(1), e86127. doi: 10.1371/journal.pone.0086127	Plastic boxes	Tap, slide, stroke, turn		Experimenter demonstrated (via video or live demonstration)
Nielsen, M., Kapitány, R., & Elkins, R. (2014). The perpetuation of ritualistic actions as revealed by young children's transmission of normative behavior. *Evolution and Human Behavior, 36*(3), 191-198. doi: 10.1016/j.evolhumbehav.2014.11.002		Tap using tools	Four opaque boxes	Experimenter demonstrated (change of location task and using opaque boxes)
Nielsen, M., Mushin, I., Tomaselli, K., & Whiten, A. (2014). Where culture takes hold: "overimitation" and its flexible deployment in Western, Aboriginal, and Bushmen children. *Child Development, 85*(6), 2169-2184. doi: 10.1111/cdev.12265	Puzzle box	Slide, taps	Puzzle box	Experimenter demonstrated
Simpson, A., & Riggs, K. J. (2011). Three- and 4-year-olds encode modeled actions in two ways leading to immediate imitation and delayed emulation. *Developmental Psychology, 47*(3), 834-840. doi: 10.1037/a0023270	Transparent box	Insert tool into top of box		Experimenter demonstrated
Watson-Jones, R. E., Legare, C. H., Whitehouse, H., & Clegg, J. M. (2014). Task-specific effects of ostracism on imitative fidelity in early childhood. *Evolution and Human Behavior, 35*(3), 204-210. doi: 10.1016/j.evolhumbehav.2014.01.004		Tap, clap	Objects (pegs and other objects)	Experimenter demonstrated (primed non/ostracism)
Yu, Y., & Kushnir, T. (2014). Social context effects in 2- and 4-year-olds' selective versus faithful imitation.		Turn a latch, lift a barrier, push a	Four opaque boxes	Experimenter demonstrated

Developmental Psychology, 50(3), 922-933. doi: 10.1037/a0034242		tray; all actions are not connected or actions that retrieve an object		
2015				
Berl, R. E. W., & Hewlett, B. S. (2015). Cultural variation in the use of overimitation by the Aka and Ngandu of the Congo Basin. *PLoS ONE, 10*(3), e0120180. doi: 10.1371/journal.pone.0120180	Horner/Whiten box	Disconnected actions		Experimenter demonstrated
Carr, K., Kendal, R. L., & Flynn, E. G. (2015). Imitate or innovate? Children's innovation is influenced by the efficacy of observed behaviour. *Cognition, 142*(0), 322-332. doi: http://dx.doi.org/10.1016/j.cognition.2015.05.005	Multiple Methods box	Reward retrieval		Experimenter demonstrated
DiYanni, C., Corriveau, K. H., Kurkul, K., Nasrini, J., & Nini, D. (2015). The role of consensus and culture in children's imitation of inefficient actions. *Journal of Experimental Child Psychology, 137*(0), 99-110. doi: http://dx.doi.org/10.1016/j.jecp.2015.04.004	Crushing cookies	Crush cookies with an inefficient tool		A single model or a consensus demonstrated
Freier, L., Cooper, R. P., & Mareschal, D. (2015). The planning and execution of natural sequential actions in the preschool years. *Cognition, 144*, 58-66. doi: 10.1016/j.cognition.2015.07.005	Making a sandwich	Various actions involving moving a bag and jar of sugar		Experimenter demonstrated
Kapitány, R., & Nielsen, M. (2015). Adopting the ritual stance: The role of opacity and context in ritual and everyday actions. *Cognition,*	Cleaning a glass	Wave a cloth in front of a glass, raise a	Ritual	Video of a single model demonstrated either the ritual or 'cleaning a glass'

145, 13-29. doi: 10.1016/j.cognition.2015.08.002		glass, bow to the glass		
Keupp, S., Behne, T., Zachow, J., Kasbohm, A., & Rakoczy, H. (2015). Over-imitation is not automatic: Context sensitivity in children's overimitation and action interpretation of causally irrelevant actions. *Journal of Experimental Child Psychology, 130*, 163-175. doi: http://dx.doi.org/10.1016/j.jecp.2014.10.005	Various boxes/activities	Throw a bead, rip paper, 'junkpress' a ball		Experimenter demonstrated
Legare, C. H., Wen, N. J., Herrmann, P., & Whitehouse, H. (2015). Imitative fidelity and the development of cultural learning. *Cognition, 142*, 351-361. doi: 10.1016/j.cognition.2015.05.020	Various objects with an end-state	A sequence of tapping objects, pressing fists together	Various objects without an end-state	Study 1: Experimenter demonstrated using non-verbal cues Study 2: Experimenter demonstrated using verbal cues
Marno, H., & Csibra, G. (2015). Toddlers favor communicatively presented information over statistical reliability in learning about artifacts. *PLoS ONE, 10*(3), e0122129. doi: 10.1371/journal.pone.0122129		Unreliable button	Wooden apparatus with lamps	Experimenter demonstrated
McGuigan, N., & Robertson, S. (2015). The influence of peers on the tendency of 3- and 4-year-old children to over-imitate. *Journal of Experimental Child Psychology, 136*(0), 42-54. doi: http://dx.doi.org/10.1016/j.jecp.2015.03.004	Horner/Whiten box	Disconnected actions		Peers demonstrated
Ronfard, S., Was, A. M., & Harris, P. L. (2016). Children teach what they could not discover. *Journal of Experimental Child Psychology, 142*, 107-117.	Transparent top of puzzle box	Use tools with different shaped ends		Experimenter demonstrated
Subiaul, F., Krajkowski, E., Price, E., & Etz, A. (2015). Imitation by		Actions are	Wooden boxes	2 models demonstrated

Combination: Preschool Age Children Evidence Summative Imitation in a Novel Problem-Solving Task. *Frontiers in Psychology, 6*(1410), 1-14. doi: 10.3389/fpsyg.2015.01410		relevant to open the box, but actions repeated three times		different actions (summative imitation)
Vredenburgh, Christopher, Kushnir, Tamar, & Casasola, Marianella. (2015). Pedagogical cues encourage toddlers' transmission of recently demonstrated functions to unfamiliar adults. *Developmental Science, 18*(4), 645-654. doi: 10.1111/desc.12233		Turn crank or wave light	Toys	Selective-one experimenter demonstrated pedagogically and the other functionally
2016				
Chudek, M., Baron, A. S., & Birch, S. (2016). Unselective overimitators: The evolutionary implications of children's indiscriminate copying of successful and prestigious models. *Child Development, 87*(3), 782-794. doi: 10.1111/cdev.12529	Rod and Pull box	Use a redundant tool by rotating it, removing rod/hinge, tapping top of the device with tool, opening top door, rotating disconnected propeller/ hinge		Experimenter demonstrated
Clegg, J. M., & Legare, C. H. (2016a). A cross-cultural comparison of children's imitative flexibility. *Developmental Psychology, 52*(9), 1435-1444. doi: 10.1037/dev0000131	Putting beads on a string, with instrumental framing: "I am going to make a necklace. Let's watch	Bring end of string together and then open, lay string out, touch beads to head before putting on the string	Putting beads on a string, with conventional framing: "Everyone always does it like this. Let's watch	Experimenter demonstrated

	what I am doing. I am going to make a necklace."		what I am doing. Everyone always does it like this."	
Clegg, J. M., & Legare, C. H. (2016b). Instrumental and conventional interpretations of behavior are associated with distinct outcomes in early childhood. *Child Development, 87*(2), 527-542. doi: 10.1111/cdev.12472	Putting beads on a string, with instrumental framing: "I am going to make a necklace. Let's watch what I am doing. I am going to make a necklace."	Bring end of string together and then open, lay string out, touch beads to head before putting on the string	Putting beads on a string, with conventional framing: "Everyone always does it like this. Let's watch what I am doing. Everyone always does it like this."	Experimenter demonstrated
Hewlett, B. S., & Roulette, C. J. (2016). Teaching in hunter–gatherer infancy. *Open Science, 3*(1). doi: 10.1098/rsos.150403	Puzzle box	Tap right/left of box, tap barrier, slide door		Experimenter demonstrated
Keupp, S., Bancken, C., Schillmöller, J., Rakoczy, H., & Behne, T. (2016). Rational over-imitation: Preschoolers consider material costs and copy causally irrelevant actions selectively. *Cognition, 147*, 85-92. doi: http://dx.doi.org/10.1016/j.cognition.2015.11.007	Various boxes/activities	Throw a bead, rip sticker, rip paper, 'junkpress' a ball		Experimenter demonstrated (live and video)
Moraru, C-A., Gomez, J-C., & McGuigan, N. (2016). Developmental changes in the influence of conventional and instrumental cues on over-imitation in 3- to 6-year-old children. *Journal of Experimental Child Psychology, 145*, 34-47. doi: http://dx.doi.org/10.1016/j.j	Horner/Whiten box	Disconnected actions		Experimenter demonstrated

ecp.2015.11.017				
Nielsen, M., Mushin, I., Tomaselli, K., & Whiten, A. (2016). Imitation, Collaboration, and Their Interaction Among Western and Indigenous Australian Preschool Children. *Child Development, 87*(3), 795-806. doi: 10.1111/cdev.12504	Clear box	Slide, taps	Opaque box	Experimenter demonstrated
Whiten, A., Allan, G., Devlin, S., Kseib, N., Raw, N., & McGuigan, N. (2016). Social learning in the real-world: 'Over-Imitation' occurs in both children and adults unaware of participation in an experiment and independently of social interaction. *PLoS One, 11*(7), e0159920. doi: 10.1371/journal.pone.0159920	Horner/Whiten box	Use tool to remove bolts, tap into hole on top of box multiple times		Confederate experimenter demonstrated
Wilks, M., Kapitány, R., & Nielsen, M. (2016). Preschool children's learning proclivities: When the ritual stance trumps the instrumental stance. *British Journal of Developmental Psychology, 34*(3), 402-414. doi: 10.1111/bjdp.12139		Tap, put hands together in a praying motion, hum	Opaque box	Individual model or group model demonstrated depending on condition
Wood, L. A., Harrison, R. A., Lucas, A. J., McGuigan, N., Burdett, E., & Whiten, A. (2016). "Model age-based" and "copy when uncertain" biases in children's social learning of a novel task. *Journal of Experimental Child Psychology, 150*, 272-284. doi: 10.1016/j.jecp.2016.06.005	Puzzle box	Tap rake on box four times and then slide rake down box four times		Experimenter demonstrated
2017				
Clay, Z., & Tennie, C. Is overimitation a uniquely human phenomenon? Insights from human children as compared to bonobos. *Child Development*. doi: 10.1111/cdev.12857		Uncommon action condition: Rub back of box in a circular motion 4x then	Opaque box	Experimenter demonstrated

		rotate wrist 4x Typical action condition: trace a diagonal on the box, then trace the diameter		
Corriveau, K. H., DiYanni, C. J., Clegg, J. M., Min, G., Chin, J., & Nasrini, J. (2017). Cultural differences in the imitation and transmission of inefficient actions. *Journal of Experimental Child Psychology, 161*, 1-18. doi: 10.1016/j.jecp.2017.03.002	Crushing cookies	Crush cookies with an inefficient tool		A single model or a consensus demonstrated
Frick, A., Clément, F., & Gruber, T. (2017). Evidence for a sex effect during overimitation: boys copy irrelevant modelled actions more than girls across cultures. *Royal Society Open Science, 4*(12). doi: 10.1098/rsos.170367	Glass bottle (Hook task)	Tap box twice on the sides and lift lid, push box forward with elbow and turn lid clockwise, lift box and pull lid up		Experimenter demonstrated
Gruber, T., Deschenaux, A., Frick, A., & Clement, F. (2017). Group membership influences more social identification than social learning or overimitation in children. *Child Development*. doi: 10.1111/cdev.12931		Lift shutter on box	Wooden box	Two experimenters demonstrated
Kapitány, R., & Nielsen, M. (2017). The ritual stance and the precaution system: the role of goal-demotion and opacity in ritual and everyday actions. *Religion, Brain & Behavior, 7*(1), 27-42. doi:	Cleaning a glass	Wave a cloth in front of a glass, raise a glass, bow to the glass	Ritual	Six conditions: A video of a single model demonstrated an action type (either the ritual or 'cleaning a glass'), and goal type (blessing, curse, or goal absent)

10.1080/2153599X.2016.1141792				
Lucas, A. J., Burdett, E. R. R., Burgess, V., McGuigan, N., Wood, L. A., Harris, P. L., & Whiten, A. (2017). Children's selective copying of their mother versus an expert. *Child Development, 88*, 2026-2042. doi: 10.1111/cdev.12711	Puzzle box	Pull handle		Confederate 'Stranger', Confederate 'Expert', or child's mother demonstrated
McGuigan, N., & Burgess, V. (2017). Is the tendency to conform influenced by the age of the majority? *Journal of Experimental Child Psychology, 157*, 49-65. doi: http://dx.doi.org/10.1016/j.jecp.2016.12.007	Horner/Whiten box	Use tool to remove bolts, tap into hole on top of box multiple times		Age of models differed by age groups; one model demonstrated efficient method and four other models demonstrated inefficient method
Schleihauf, H., Graetz, S., Pauen, S., & Hoehl, S. (2017). Contrasting social and cognitive accounts on overimitation: The role of causal transparency and prior experiences. *Child Development*. doi: 10.1111/cdev.12780	Clear box with clear tube	Clap, push a lever attached top of box, tap outside box, tap hand		Experiment 1: Experimenter A first demonstrates an efficient action and lets child interact with tube, then Experimenter B demonstrates inefficient actions Experiment 2: Experimenter A demonstrated an efficient action communicatively or non-communicatively, then Experimenter B demonstrated an inefficient action communicatively
Taniguchi, Y., & Sanefuji, W. (2017). The boundaries of overimitation in preschool children: Effects of target and tool use on imitation of irrelevant actions. *Journal of Experimental Child Psychology, 159*, 83-95. doi: 10.1016/j.jecp.2017.01.014	Clear box	Condition 1: Tap, draw on, rub, push the box with a tool Condition 2: Tap, draw on, rub and push on the palm		Experimenter demonstrated

		of hand with a tool		
Vivanti, G., Hocking, D. R., Fanning, P., & Dissanayake, C. (2017). The social nature of overimitation: Insights from Autism and Williams syndrome. *Cognition, 161*, 10-18. doi: 10.1016/j.cognition.2017.01.008	Three clear boxes	Either tap the sides of the box, push container forward with elbow, or lift container up		Experimenter demonstrated

869

870

871