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

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**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

58 Highlights:

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

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87                   The interaction of social and perceivable causal factors in shaping ‘over-imitation’

88   1.1 Introduction

89   Compared to any other species, humans have an enormous propensity to acquire cultural  
90   knowledge (Henrich, 2015; Pagel, 2013). This ability is commonly attributed, at least in part, to an  
91   early-developing tendency for high fidelity imitation of the behaviors, skills, and actions of others  
92   (Dean, Kendal, Schapiro, Thierry, & Laland, 2012; Schillinger, Mesoudi, & Lycett, 2015; Tennie, Call, &  
93   Tomasello, 2009; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). The disposition to copy  
94   others has been found to extend in some contexts to children and adults imitating apparently  
95   indiscriminately, extending to the copying of even visibly irrelevant or causally superfluous actions  
96   (Horner & Whiten, 2005; McGuigan, Whiten, Flynn, & Horner, 2007). It has been suggested that this  
97   phenomenon, dubbed “over-imitation” (Lyons, Young, & Keil, 2007) can, in normal daily life,  
98   facilitate the spread of cultural knowledge, particularly when skills pertain to tasks that are causally  
99   opaque or too difficult for a naive learner to learn on his or her own (Lyons, Damrosch, Lin, Macris, &  
100   Keil, 2011; Lyons et al., 2007; Nielsen, Mushin, Tomaselli, & Whiten, 2014), or to behaviors that are  
101   associated with rituals or other normative conventions (Herrmann, Legare, Harris, & Whitehouse,  
102   2013; Kapitány & Nielsen, 2015, 2017; Keupp, Behne, & Rakoczy, 2013; Keupp, Behne, Zachow,  
103   Kasbohm, & Rakoczy, 2015; Legare, Wen, Herrmann, & Whitehouse, 2015; Watson-Jones, Legare,  
104   Whitehouse, & Clegg, 2014; Wilks, Kapitány, & Nielsen, 2016). However, a number of other studies  
105   have shown that children and adults are not necessarily indiscriminate imitators; in some contexts  
106   they may be selective instead (see for example, Gergely, Bekkering, & Kiraly, 2002; Hilbrink,  
107   Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013; Nielsen, 2006). Identifying the potentially interacting  
108   factors that modulate over-imitation is accordingly important to understanding how children learn  
109   new skills and cultural knowledge from others. In this spirit the present study examines the limits  
110   and selectivity of children’s motivational tendency to copy others, exploring a potential interplay  
111   between social and causal factors that may interact in underpinning over-imitation.

112           In many over-imitation experiments children and adults watch a model perform several actions,  
113   some causally relevant and some visibly causally irrelevant. In an initial study, Horner and Whiten  
114   (2005) showed children either an opaque or transparent puzzle box and performed a series of  
115   causally irrelevant and relevant actions on it before extracting a reward from the box. Regardless of  
116   whether the puzzle box was opaque or transparent (so in the latter, causal irrelevance appeared  
117   highly visible), children copied the irrelevant actions. What Lyons and colleagues later called “over-  
118   imitation”, became identified as a pervasive tendency to imitate a series of actions even in the face  
119   of visual information that these actions have no causal relevance to the task solution (Horner &

120 Whiten, 2005; Lyons et al., 2007). Later research has therefore concentrated much on the  
121 transparent versions of such tasks, showing that children may continue to copy irrelevant actions  
122 even under time constraints (Lyons et al., 2011; Lyons et al., 2007), even when they are given the  
123 opportunity of prior experience with how the task works (Nielsen & Tomaselli, 2010), and even  
124 when they have been schooled that irrelevant actions are ‘silly and unnecessary’ (Lyons et al., 2011;  
125 Lyons et al., 2007). Such effects have further been documented after children’s personal exploration  
126 of tasks, despite an irrelevant action occurring after retrieving an award (Wood, Kendal, & Flynn,  
127 2013a), with children who live in quite different cultures (Berl & Hewlett, 2015; Nielsen, Mushin, et  
128 al., 2014; Nielsen & Tomaselli, 2010), and despite the absence of any social interaction or audience  
129 (Whiten et al., 2016).

130 A large part of this literature has thus focused on investigating the motivation to over-imitate in  
131 the kinds of transparent conditions that first revealed the phenomenon so starkly (Berl & Hewlett,  
132 2015; Brugger, Lariviere, Mumme, & Bushnell, 2007; Carr, Kendal, & Flynn, 2015; Chudek, Baron, &  
133 Birch, 2016; Flynn, 2008; Flynn & Smith, 2012; Freier, Cooper, & Mareschal, 2015; Frick, Clément, &  
134 Gruber, 2017; Hoehl, Zettersten, Schleihauf, Grätz, & Pauen, 2014; Horner & Whiten, 2005;  
135 Kenward, 2012; Kenward, Karlsson, & Persson, 2011; Keupp, Bancken, Schillmöller, Rakoczy, &  
136 Behne, 2016; Keupp et al., 2015; Lucas et al., 2017; Lyons et al., 2011; Lyons et al., 2007; Marsh,  
137 Pearson, Ropar, & Hamilton, 2013; Marsh, Ropar, & Hamilton, 2014; McGuigan, 2012, 2013;  
138 McGuigan & Burgess, 2017; McGuigan, Gladstone, & Cook, 2012; McGuigan, Makinson, & Whiten,  
139 2011; McGuigan & Whiten, 2009; Moraru, Gomez, & McGuigan, 2016; Nielsen, 2013; Ronfard, Was,  
140 & Harris, 2016; Schleihauf, Graetz, Pauen, & Hoehl, 2017; Simpson & Riggs, 2011; Taniguchi &  
141 Sanefuji, 2017; Vivanti, Hocking, Fanning, & Dissanayake, 2017; Whiten et al., 2016; Wood et al.,  
142 2016; Wood, Kendal, & Flynn, 2012; Wood et al., 2013a). Less work has explored what is more likely  
143 to be the natural functional context of over-imitation, the everyday world of largely opaque (and  
144 moreover causally opaque) objects (Buchsbaum, Gopnik, Griffiths, & Shafto, 2011; Clay & Tennie,  
145 2017; Gardiner, 2014; Gruber, Deschenaux, Frick, & Clement, 2017; Herrmann et al., 2013; Marno &  
146 Csibra, 2015; McGuigan et al., 2007; Nielsen, Cucchiaro, & Mohamedally, 2012; Nielsen & Hudry,  
147 2010; Nielsen, Moore, & Mohamedally, 2012; Nielsen, Mushin, et al., 2014; Nielsen, Tomaselli,  
148 Mushin, & Whiten, 2014; Subiaul, Krajkowski, Price, & Etz, 2015; Watson-Jones et al., 2014).

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

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

160 Based on prior work in transparent conditions where the irrelevancy of actions is visibly  
161 apparent, we know that over-imitation can be limited or modulated by several factors. For example,  
162 a diminution of over-imitation can occur based on either social or causal cues. When children are  
163 presented with causal information via one model who demonstrates a more efficient method and  
164 another model who demonstrates an inefficient one (McGuigan & Robertson, 2015; Nielsen & Blank,  
165 2011; Schleihauf et al., 2017), or when there is visual confirmation that the actions are superfluous  
166 (Gardiner, 2014), they are less likely to over-imitate, instead tending to adopt the relatively efficient  
167 method. Additional research shows that children are sensitive to the relevance of the  
168 communicative intent of others, and over-imitation may decrease when children receive a salient  
169 social cue from a model that only the casually relevant elements of the demonstration need to be  
170 copied (Brugger et al., 2007; Buchsbaum et al., 2011; Gergely et al., 2002; Nielsen, 2006; Southgate,  
171 Chevallier, & Csibra, 2009; Vredenburg, Kushnir, & Casasola, 2015).

172 Other social factors have been shown to encourage over-imitation. More specifically, studies  
173 demonstrate that children are more likely to imitate irrelevant actions when they perceive ostensive  
174 or pedagogical cues that the demonstrator is going to communicate relevant information (Gergely &  
175 Csibra, 2005) and that this is the way an action “ought to be done” (Bonawitz et al., 2011; Herrmann  
176 et al., 2013; Kapitány & Nielsen, 2015, 2017; Kenward et al., 2011; Keupp et al., 2013; Keupp et al.,  
177 2015; Watson-Jones et al., 2014). More normative framing (e.g., doing something that “ought to be  
178 done”) and goal demoted actions (e.g., actions with no known goal) increases children’s imitative  
179 fidelity compared to instrumental framing (e.g., doing something “to get prizes”) and tasks with a  
180 clear goal (e.g., retrieving prizes or putting an object in a box) (Clegg & Legare, 2016b; Legare et al.,  
181 2015; Nielsen, Kapitány, & Elkins, 2015; Wilks et al., 2016).

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

186 functions of over-imitation and the kind of flexible decision making that shapes it. Accordingly, in  
187 the present study we explored, for what is to our knowledge the first time, the interplay between  
188 the physically causal factors and the social factors that underpin over-imitation. In a 2 x 2 design,  
189 participants in four conditions watched two (live) adult models, in a counterbalanced sequence,  
190 perform either an inefficient method (incorporating causally-unnecessary elements) or an efficient  
191 method (lacking the causally-unnecessary element). In each of the four conditions we held the one  
192 inefficient model/one efficient model design constant while we manipulated two factors that may  
193 be predicted to increase or decrease the likelihood of over-imitation: first, whether children  
194 experienced a transparent or opaque puzzle box, and second whether children received social  
195 information (in combination with experiencing a transparent or opaque puzzle box) regarding which  
196 model was more knowledgeable (see Table 1). For the latter, we designed a social information  
197 condition where the 'inefficient' model was taught, in the presence of the participant, to use the  
198 inefficient method by another person. This design enabled us to explore whether witnessing the  
199 teaching episode would be sufficiently influential to override the greater efficiency of the alternative  
200 method modelled by the naïve demonstrator. We tested participants from two different age groups  
201 (4- and 5-year-olds and 6- and 7-year-olds), as previous work has shown that over-imitation tends to  
202 increase with age (McGuigan & Graham, 2010; McGuigan et al., 2007).

203 [Table 1 here]

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

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

## 229 **2.1 Method**

### 230 **2.1.1 Participants**

231 Two age groups were recruited for each of four experimental conditions: a 4-to-5-year-old group ( $n$   
232 = 83, 41 females, 42 males; *mean age* = 59 months, *SD* = 7.09 months, range 48-72 months) and a 6-  
233 to-7-year-old group ( $n$  = 82, 48 females, 34 males; *mean age* = 83 months, *SD* = 6.96 months, range  
234 72 - 106 months). Forty children (20 4-to-5-year-olds and 20 6-to-7-year-olds) were assigned to a  
235 *Transparent box - Baseline* condition, 46 children (23 4-to-5-year-olds and 23 6-to-7-year-olds) to a  
236 *Transparent - Taught* condition, 39 children (19 4-to-5-year-olds and 20 6-to-7-year-olds) to an  
237 *Opaque - Baseline* condition, and 40 children (21 4-to-5-year-olds and 19 6-to-7-year-olds) to an  
238 *Opaque - Taught* condition.

### 239 **2.1.2 Apparatus**

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



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

252 [Figure 1 here]

### 253 **2.1.3 Design**

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

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

### 266 **2.1.4 Procedure**

267 All children were tested individually in a large gazebo in a quiet area of Edinburgh Zoo. Children and  
268 their parents were invited to participate and if they agreed, the child was led into the gazebo and  
269 seated at a small table across from the experimenter. The experimenter then invited the child to  
270 pick out a prize (e.g., a small plastic monkey) that they would like to earn. The experimenter told the  
271 child, “Here is the puzzle box. In a little while I’m going to put your prize inside the box. But, the box  
272 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  
273 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  
274 box was placed under the table and out of sight before the experimenter left the gazebo. Two  
275 confederates of the experimenter were waiting outside the testing area and were brought inside  
276 and asked to sit on either side of the child, where they then acted as the two alternative models in  
277 the experiment.

278 After the confederates and child were seated, the experimenter said, “Thank you - all of you  
279 - for helping me today. My name is [experimenter’s name]. What are your names? Great. Now,  
280 [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

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

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

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

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

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

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

### 321 **2.1.5 Coding**

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

330           We also coded an “irrelevance index.” This index ranged from 0 to 6. Children were  
331 awarded one point for each bolt removed (maximum 2) and one point for each tap, up to four. Only  
332 12 children tapped more than three times; these children tapped between 5-8 times and were  
333 spread across all four conditions; accordingly we judged that capping scores in this way was the  
334 most apt approach. A score of 0 thus indicated that children did not perform any irrelevant action.  
335 A score of 5 was given to children who reproduced the irrelevant actions exactly as in the  
336 demonstration by the inefficient model (removing two bolts and tapping three times) and a score of  
337 6 was given to children who performed even more (e.g., tapping more than three times).

## 338 **3.1 Results**

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

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

353 [Figure 2 here]

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

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

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

377 3.21,  $SD = 0.48$ ,  $p = 0.25$ ; or the *Transparent* box, *Baseline*,  $M = 0.5$ ,  $SD = 0.46$ , *Taught*,  $M = 1.13$ ,  $SD =$   
378  $0.43$ ,  $p = 0.25$ .

379 A further comparison showed one other difference but between age groups. In the *Opaque*  
380 - *Taught* condition, there were significant differences in the adoption of irrelevant actions between  
381 age groups, with the older children reproducing significantly more irrelevant actions,  $M = 3.21$ ,  $SD =$   
382  $2.37$ , than the younger group,  $M = 1.38$ ,  $SD = 1.98$ ,  $p = 0.006$ .

383 [Figure 3 here]

#### 384 **4.1 Discussion**

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

##### 397 **4.1.1 Acquiring skills in a world of opaque and transparent objects**

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

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

419           However, new work has shown that children have some flexibility and can be selective when  
420 copying. The above studies were presented with only one model demonstrating an action. When in  
421 our experiment we included a second model who omitted the unnecessary action with the  
422 transparent box, the modal response in both baseline and taught conditions, and in both age groups,  
423 was to copy this model and thus not to display over-imitation (left half of Fig. 2). This suggests that  
424 over-imitation is not automatic, insofar as children across this age range are generally quick to  
425 recognize, through the more efficient actions of one model and the transparency of what happens in  
426 the transparent box, that certain actions are not worth copying, even though they do not see  
427 whether the approaches of either model are successful or not. This suggests that although over-  
428 imitation can be a robust phenomenon in one-model contexts, it is at the same time fragile in being  
429 undermined by contrary information derived from the actions of others. This conclusion is consistent  
430 with the results of some other experiments that employed two models that differed in displaying  
431 necessary and unnecessary acts (Hoehl et al., 2014; McGuigan & Robertson, 2015; Nielsen & Blank,  
432 2011), or otherwise showed that over-imitation can be flexibly, and arguably rationally, adjusted to  
433 contextual variables (Keupp et al., 2015, 2016). Nevertheless, we must note that over-imitation was  
434 still displayed in the two-model and transparent artefact conditions; around as many as one third of  
435 the children copied what the inefficient model did (33% in the *Transparent - Baseline* and 28% in the  
436 *Transparent - Taught* conditions; left half of results in Fig. 2).

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

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

#### 450 **4.1.2 The influence of social information: third party pedagogy**

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

466 At first sight it may appear paradoxical that on the one hand, the older children were the  
467 more sophisticated, in taking into account the combination of pedagogic information transfer and  
468 task opacity in their choice of task solution, yet on the other, they performed more over-imitation,  
469 leading them to adopt the solution that was least effective because it incorporated causally  
470 unnecessary elements. The latter is consistent with earlier studies finding more over-imitation in  
471 older and more cognitively sophisticated children (and indeed in adults), not less (McGuigan et al.  
472 2011; Nielsen & Tomasselli, 2010). We submit that in fact there is no paradox here, insofar as the

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

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

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

#### 500 **4.1.3 Conclusion**

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



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

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698 *Australian Journal of Psychology*, 62(2), 67-74. doi: 10.1080/00049530902758613
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- 729 Simpson, A., & Riggs, K. J. (2011). Three- and 4-year-olds encode modeled actions in two ways  
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747 transmission of recently demonstrated functions to unfamiliar adults. *Developmental*  
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751 210. doi: 10.1016/j.evolhumbehav.2014.01.004
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755 world: 'Over-Imitation' occurs in both children and adults unaware of participation in an  
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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*  
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- 761 Wilks, M., Kapitány, R., & Nielsen, M. (2016). Preschool children's learning proclivities: When the  
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765 based" and "copy when uncertain" biases in children's social learning of a novel task. *Journal*  
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- 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

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782 *Table 1.*

783 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)

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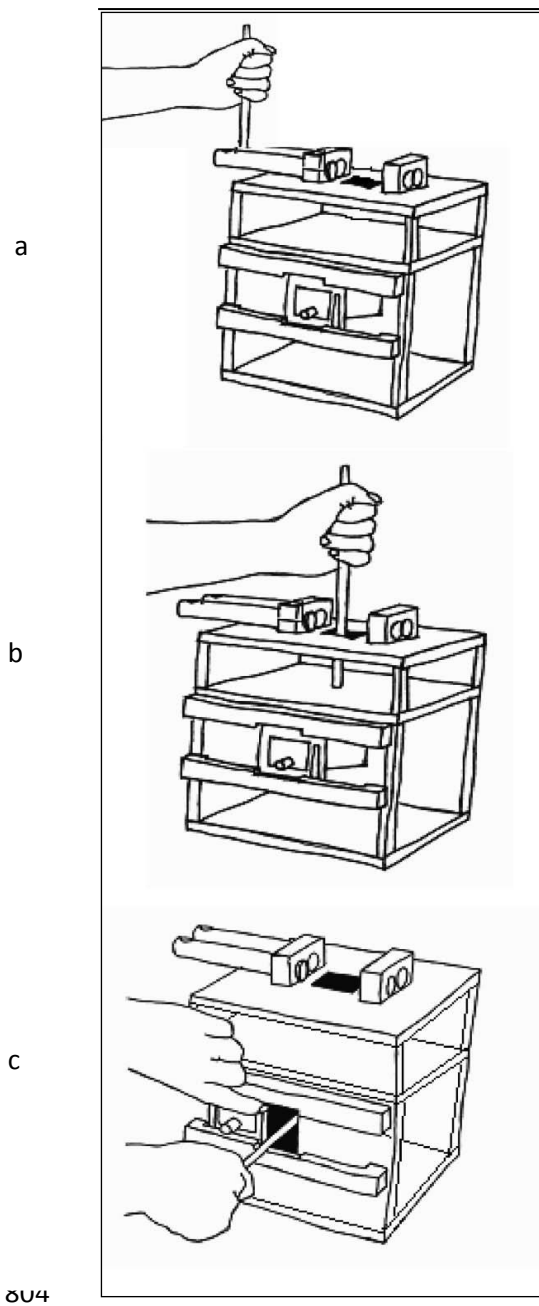
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805 *Figure 1.* The ‘model’ demonstrates a series of actions, some of which are causally irrelevant to goal  
806 retrieval (removing bolt defence, inserting tool into top hole), and some which are causally relevant  
807 to goal retrieval (removing 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.

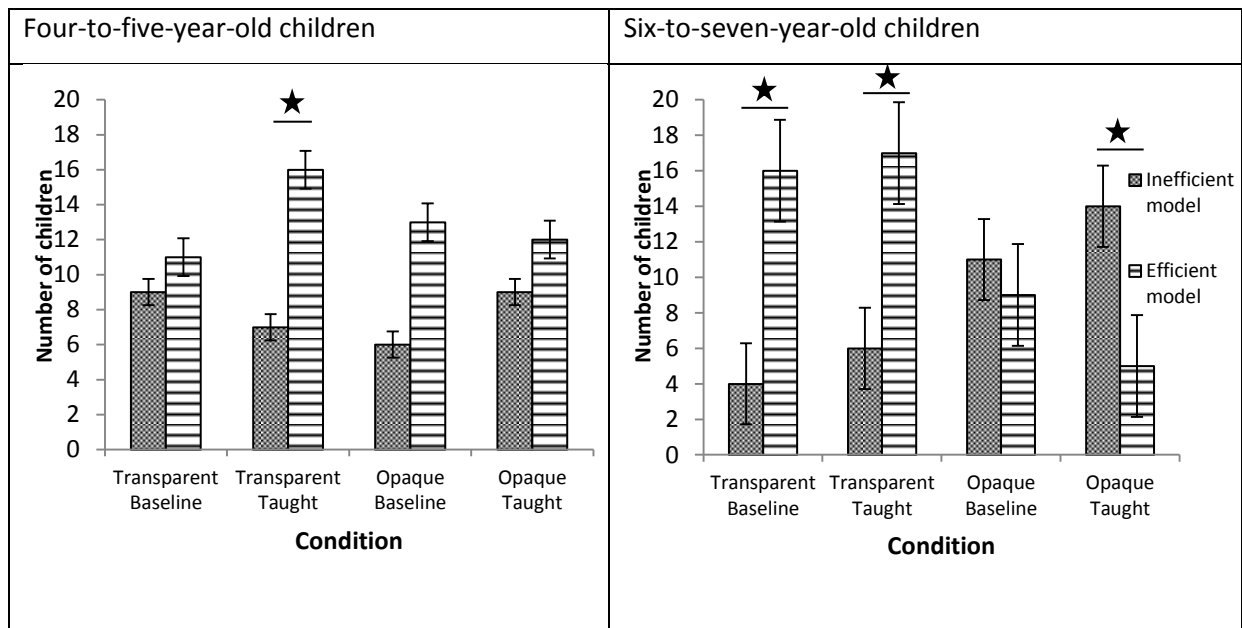
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815 *Figure 2.* Number of children who copied the efficient and inefficient models, by age group and  
 816 condition. \* denotes  $p < 0.05$ ; see text for details.

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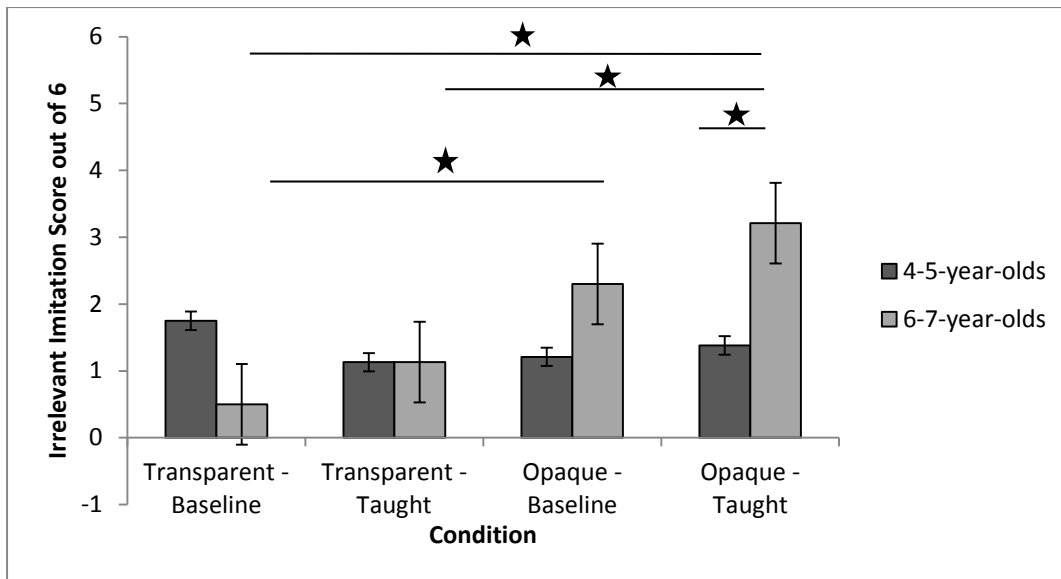
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825 *Figure 3.* Mean number of irrelevant actions by condition and age group. \* denotes  $p < 0.05$ .

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

Study	Transparent Object/Activity	Irrelevant actions	Opaque Object/Activity	Type of model demonstration
<b>2002</b>				
Gergely, G., Bekkering, H., & Kiraly, I. (2002). Developmental psychology: Rational imitation in preverbal infants. <i>Nature</i> , 415(6873), 755-755.	Tough light with hands	Touch light with head	Touch light with forehead	Experimenter demonstrated
<b>2005</b>				
Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees ( <i>Pan troglodytes</i> ) and children ( <i>Homo sapiens</i> ). <i>Animal Cognition</i> , 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
<b>2006</b>				
Nielsen, M. (2006). Copying actions and copying outcomes: social learning through the second year. <i>Developmental Psychology</i> , 42(3), 555-565. doi: 10.1037/0012-1649.42.3.555		Object directed actions to activate box	Three opaque boxes	Experimenter demonstrated
<b>2007</b>				
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. <i>Child Development</i> , 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. <i>Proceedings of the National Academy of Sciences</i> , 104(50), 19751-19756. doi: 10.1073/pnas.0704452104	Horner/W hiten 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. <i>Cognitive Development</i> , 22, 353-364. doi: 10.1016/j.cogdev.2007.01.001	Horner/W hiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/W hiten box	Watched live or video demonstration, or no demonstration
<b>2008</b>				
Flynn, E. (2008). Investigating children as cultural magnets: do young children transmit redundant information along diffusion chains? <i>Philosophical Transactions of the Royal Society B: Biological Sciences</i> , 363(1509), 3541-3551.	Horner/W hiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/W hiten 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. <i>Journal of Experimental Child Psychology</i> , 104(4), 367-381. doi: 10.1016/j.jecp.2009.07.001	Horner/W hiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/W hiten box	Experimenter then child demonstrated
<b>2009</b>				
Southgate, V., Chevallier, C., & Csibra, G. (2009). Sensitivity to communicative relevance tells young children what to imitate. <i>Developmental Science</i> , 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. <i>Journal of Experimental Child Psychology</i> , 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
<b>2010</b>				
McGuigan, N., & Graham, M. (2010). Cultural transmission of irrelevant tool actions in diffusion chains of 3- and 5-year-old children. <i>European Journal of Developmental Psychology</i> , 7(5), 561-577. doi: 10.1080/17405620902858125	Horner/W hiten box	Use tool to remove bolt, tap into hole on top of box three times	Horner/W hiten 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. <i>Psychological Science</i> . 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. <i>Australian Journal of Psychology</i> , 62(2), 67-74. doi: 10.1080/00049530902758613		Object directed actions to activate box	Three opaque boxes	Experimenter demonstrated (Children with ASD and DS)
<b>2011</b>				
Buchsbaum, D., Gopnik, A., Griffiths, T. L., & Shafto, P. (2011). Children's imitation of causal action sequences is influenced by statistical and pedagogical evidence. <i>Cognition</i> , 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. <i>Proceedings of the Royal Society. Biological sciences</i> , 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. <i>Philosophical Transactions of the Royal Society of London B: Biological Sciences</i> , 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. <i>British Journal of Psychology</i> , 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. <i>Developmental Psychology</i> , 47(4), 1050-1053. doi: 10.1037/a0023866		Swipe or tap outside of the box	2 Wooden apparatus	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. <i>Developmental Psychology</i> , 47(3), 834-840. doi: 10.1037/a0023270	Puzzle box	Open top aperture		Experimenter demonstrated
<b>2012</b>				
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

<i>Social psychology</i> , 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. <i>Child Development</i> , 83(3), 911-925. doi: 10.1111/j.1467-8624.2012.01747.x	Horner/W hiten box	Use tool to remove bolts, tap into hole on top of box once or three times	Horner/W hiten 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. <i>Journal of Experimental Child Psychology</i> , 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. <i>Journal of Comparative Psychology</i> , 126(2), 150-160. doi: 10.1037/a0025525	Horner/W hiten box	Use tool to remove bolts, tap into hole on top of box once or three times	Horner/W hiten 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? <i>PLoS ONE</i> , 7(12), e50863. doi: 10.1371/journal.pone.0050863	Horner/W hiten 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. <i>Journal of Experimental Child Psychology</i> , 112(1), 73-83. doi: <a href="http://dx.doi.org/10.1016/j.jecp.2012.01.001">http://dx.doi.org/10.1016/j.jecp.2012.01.001</a>		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. <i>PLoS ONE</i> , 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. <i>Evolution and Human Behavior</i> , 33(4), 387-394. doi: <a href="http://dx.doi.org/10.1016/j.evolhumbehav.2011.11.010">http://dx.doi.org/10.1016/j.evolhumbehav.2011.11.010</a>	Horner/W hiten box	Use tool to remove bolt, tap into hole on top of box three times		Adult/child models demonstrated (professing ignorance/knowledge)
<b>2013</b>				
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. <i>Cognition</i> , 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. <i>Developmental Science</i> , 16(6), 828-840. doi: 10.1111/desc.12070		Remove a strap to open a lid on a box (necessar y condition) or remove a strap then opening a lid (unnecess ary condition)	Opaque boxes	Experimenter demonstrated
Keupp, S., Behne, T., & Rakoczy, Hannes. (2013). Why do children overimitate? Normativity is crucial. <i>Journal of Experimental Child Psychology</i> , 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. <i>Journal of Experimental Child Psychology</i> , 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. <i>Current Biology</i> , 23(7), R266-R268. doi: <a href="http://dx.doi.org/10.1016/j.cub.2013.02.036">http://dx.doi.org/10.1016/j.cub.2013.02.036</a>	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. <i>Journal of Experimental Child Psychology</i> , 116(4), 962-969. doi: 10.1016/j.jecp.2013.05.004	Horner/W hiten box	Disconnec ted 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. <i>Infant and Child Development</i> , 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. <i>Autism Research</i> , 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. <i>Developmental Psychology</i> , 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. <i>Cognition</i> , 127(2), 203-213. doi: 10.1016/j.cognition.2013.01.002	Sweep-drawer box	Irrelevant actions after the prize fell		Puppet demonstrated
<b>2014</b>				
Gardiner, A. K. (2014). Beyond irrelevant actions: understanding the role of intentionality in children's imitation of relevant actions. <i>Journal of Experimental Child Psychology</i> , 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. <i>Journal of Experimental Child Psychology</i> , 122(0), 122-133. doi: <a href="http://dx.doi.org/10.1016/j.jecp.2013.12.012">http://dx.doi.org/10.1016/j.jecp.2013.12.012</a>	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. <i>PLOS ONE</i> , 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. <i>Evolution and Human Behavior</i> , 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. <i>Child Development</i> , 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. <i>Developmental Psychology</i> , 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. <i>Evolution and Human Behavior</i> , 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

<i>Developmental Psychology</i> , 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. <i>PLoS ONE</i> , 10(3), e0120180. doi: 10.1371/journal.pone.0120180	Horner/W hiten 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. <i>Cognition</i> , 142(0), 322-332. doi: <a href="http://dx.doi.org/10.1016/j.cognition.2015.05.005">http://dx.doi.org/10.1016/j.cognition.2015.05.005</a>	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. <i>Journal of Experimental Child Psychology</i> , 137(0), 99-110. doi: <a href="http://dx.doi.org/10.1016/j.jecp.2015.04.004">http://dx.doi.org/10.1016/j.jecp.2015.04.004</a>	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. <i>Cognition</i> , 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. <i>Cognition</i> ,	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. <i>Journal of Experimental Child Psychology</i> , 130, 163-175. doi: <a href="http://dx.doi.org/10.1016/j.jecp.2014.10.005">http://dx.doi.org/10.1016/j.jecp.2014.10.005</a>	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. <i>Cognition</i> , 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. <i>PLoS ONE</i> , 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. <i>Journal of Experimental Child Psychology</i> , 136(0), 42-54. doi: <a href="http://dx.doi.org/10.1016/j.jecp.2015.03.004">http://dx.doi.org/10.1016/j.jecp.2015.03.004</a>	Horner/W hiten box	Disconnected actions		Peers demonstrated
Ronfard, S., Was, A. M., & Harris, P. L. (2016). Children teach what they could not discover. <i>Journal of Experimental Child Psychology</i> , 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

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

	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. <i>Child Development, 87</i> (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. <i>Open Science, 3</i> (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. <i>Cognition, 147</i> , 85-92. doi: <a href="http://dx.doi.org/10.1016/j.cognition.2015.11.007">http://dx.doi.org/10.1016/j.cognition.2015.11.007</a>	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. <i>Journal of Experimental Child Psychology, 145</i> , 34-47. doi: <a href="http://dx.doi.org/10.1016/j.j">http://dx.doi.org/10.1016/j.j</a>	Horner/W hiten box	Disconnected actions		Experimenter demonstrated

<a href="#">ecp.2015.11.017</a>				
Nielsen, M., Mushin, I., Tomaselli, K., & Whiten, A. (2016). Imitation, Collaboration, and Their Interaction Among Western and Indigenous Australian Preschool Children. <i>Child Development</i> , 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. <i>PLoS One</i> , 11(7), e0159920. doi: 10.1371/journal.pone.0159920	Horner/W hiten 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. <i>British Journal of Developmental Psychology</i> , 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. <i>Journal of Experimental Child Psychology</i> , 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
<b>2017</b>				
Clay, Z., & Tennie, C. Is overimitation a uniquely human phenomenon? Insights from human children as compared to bonobos. <i>Child Development</i> . 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. <i>Journal of Experimental Child Psychology</i> , 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. <i>Royal Society Open Science</i> , 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. <i>Child Development</i> . 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. <i>Religion, Brain &amp; Behavior</i> , 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. <i>Child Development, 88</i> , 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? <i>Journal of Experimental Child Psychology, 157</i> , 49-65. doi: <a href="http://dx.doi.org/10.1016/j.jecp.2016.12.007">http://dx.doi.org/10.1016/j.jecp.2016.12.007</a>	Horner/W hiten 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. <i>Child Development</i> . 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. <i>Journal of Experimental Child Psychology, 159</i> , 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. <i>Cognition</i> , 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

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